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CONTENTS AND INDEX

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VOL. XIV. JANUARY, 1895. No. 1.

THE ST. LOUIS WATER WORKS.

I. Historical.

BY M. L. HOLMAN, MEMBER OF THE ENGINEERS' CLUB OF ST. LOUIS.

[Read March 7, 1894.*]

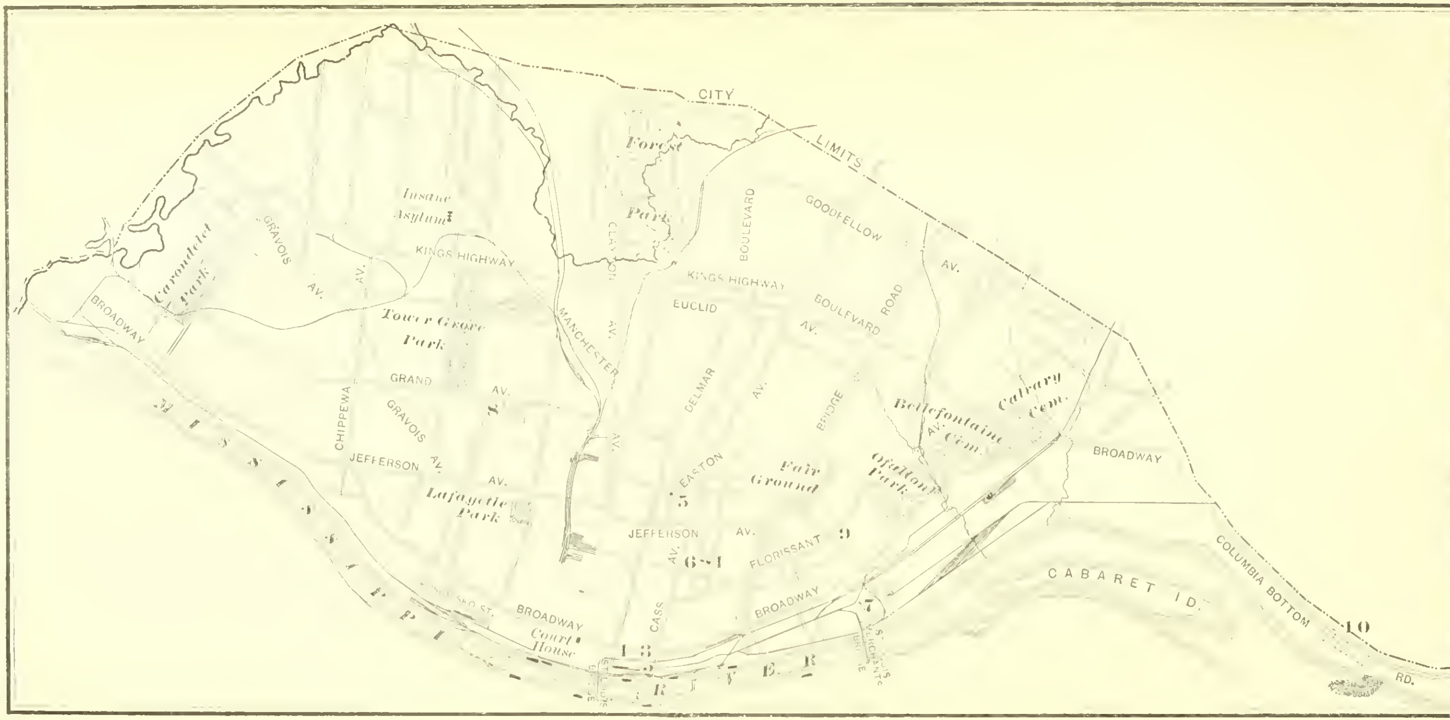
IN opening the series of addresses on the St. Louis Water Works, I will give, as my contribution, what history I have been able to collect from public documents and other sources.

In the year 1829 the city of St. Louis contracted with Messrs. John C. Wilson and Abraham Fox for the building and operating of a water works to supply "clarified" water for a term of twenty-five years; the works to belong to the city at the expiration of the contract.

This contract gave the contractors the exclusive right to supply water for public and private purposes, the charges being limited to $20 per year for families and $100 per year for hotels and manufactories. The city further conceded a bonus of $3,000 cash on the completion of the works; a lot of ground 40 feet by 125 feet on the river bank and a half acre of ground for a reservoir site.

In 1830 the city purchased of William H. Ashley a lot of ground 170 feet by 160 feet on the "little mound" located at the corner of Ashley and Collins Streets for a reservoir site, and a lot 250 feet by 250 feet from the U. S. Government for a pumping site.

* Manuscript for this series of papers received from November 24, 1894, to January 19, 1895.—*Secretary Assn. Eng. Socs.*



City of St. Louis.—Skeleton Map.

1. Little Mound, Ashley and Collins Sts.
2. Site for Pumping Station, foot of Smith St.
3. Reservoir, Bates and Collins Sts.
4. Benton St. Reservoir.
5. Park.—Former site of Temporary Reservoir, Gamble St. near Garrison St.
6. Reservoir built 1854–5.
7. Bissell's Point Works.
8. Compton Hill Reservoir.
9. Standpipe of Bissell's Point System.
10. New Water Works at Chain of Rocks.

The contractors were to supply, free of charge, water to twelve fire hydrants, the hospital of the Sisters of Charity and a fountain on the grounds of William Ashley. The water was to be distributed through cast-iron pipes laid not less than $3\frac{1}{2}$ feet under ground. Water was to be delivered to the reservoir in one year and to the hydrants in eighteen months.

But little progress was made under this contract, notwithstanding the fact that the then mayor, Daniel D. Page, gave his private note to secure payment for water pipe ordered of Vanleer & Company. The contractors were forced by want of capital to suspend work, and the city was forced into a new contract, dated April 2, 1831, with Mr. Fox, in which he was released from all the conditions of the first contract except the fountain for Mr. Ashley; this fountain being a part of the consideration in the purchase of the reservoir site. In this contract the city agreed to assume three-fourths of all expenses and take charge of and complete the works.

The city borrowed $25,000 in 1831 in order to proceed with the works. The supply of water was in all probability begun in the fall of 1831. Old reports refer to this date, but positive statements of water supply do not appear until the summer of 1832.

The early management was under the care of a committee of the City Council, and it appears that the work was carefully conducted. Until 1847 the plumbing and all work connected with the supply of private houses was conducted solely by the city, which manufactured for that purpose its own lead pipe and fixtures.

In July, 1835, the city purchased the interest of Mr. Fox in the works, paying $18,000 therefor.

The total cost of the works to this time was about $54,000, not including interest-bearing notes given in pay for pipe. The city then became sole owner of its water works.

The first pumping engine was built for the works by Francis Pratt, of Pittsburg. The steam cylinder was 10 inches diameter by 4 feet stroke. The pump was double-acting, and the piston was 6 inches in diameter and of 4 feet stroke. This engine proved to be a failure and was replaced by two rotary pumps which the city had purchased for fire engines. These rotaries were set up in a small building at the foot of Smith Street. The water was delivered into a reservoir at the corner of Bates and Collins Streets. This was the first reservoir used by this city. The reservoir was 62 feet by 55 feet, with a depth of 15 feet. The flow line was 90 feet above the city directrix. The walls were of masonry, lined with brick, and the bottom was paved with brick on a tight plank floor.

These facilities supplied sufficient water for ordinary uses, but failed

to give an adequate fire supply on account of the smallness of the distribution pipes. Although a settling basin was constructed near the engine house it does not appear to have been used, all evidence going to show that water was pumped direct to the city reservoir without settling.

In 1836 a new pump main 10 inches in diameter was laid, and in 1839 a new engine was started. It was direct-acting. The steam cylinder was 13 inches and the water cylinder 13 inches in diameter, and both were of 6 feet stroke.

In 1838 a new pump main 12 inches in diameter was laid and a new reservoir was decided upon, but the project was abandoned.

In 1845 a new reservoir was erected on the site of the old one. It was a wooden tank 100 feet square by 12 feet deep. The walls of the old reservoir were used as a support for the middle part of the bottom, and a dry stone wall was laid up to carry the edges of the tank. The tank rested on these walls and on intermediate posts. It was built of oak, framed and spiked, and the seams were caulked with oakum.

The use of both reservoirs continued, the upper one being used for supplying the higher districts. It seems that the city was at that time divided into two districts.

After a few years' use of the double system, the old, or lower level, reservoir was abandoned and the distribution was thrown onto the upper reservoir. By the year 1849 frequent repairs to the wooden tank became necessary, and in 1852 it was abandoned.

In 1846 the superintendent of the works first suggested that the supply of water for the city be drawn from the Meramec River. The discussion on this question continued until 1854, when the then superintendent reported against the scheme.

In 1846 the third pumping engine was erected. The machine was of the crank and fly-wheel type. The steam cylinder was 20 inches diameter by 7½ feet stroke. The pump was double-acting, 15 inches diameter and of the same stroke as the steam engine. The engine gave trouble on account of bad foundations, and in 1847 it "laid down" and was rebuilt. In 1852 the fourth engine, costing $25,000, was erected; steam cylinder, 26 inches diameter by 10 feet stroke; pump, double-acting, piston, 22 inches diameter by 10 feet stroke. It was originally started as a condensing engine, but the condenser was abandoned in 1852.

In 1847 the third reservoir was begun. This was the old Benton Street Reservoir. It was 250 feet square, with a working depth of 15 feet. Elevation of flow line, 115½ feet above datum, cost $74,000 (approximate). The pump main to this reservoir was a 20-inch cast-iron pipe and was laid up Mullanphy Street. The reservoir was finished in 1849. It was provided with a sloping bottom and a system of flushing

sewers for the purpose of removing sediment, but the scheme was a failure.

In 1854 the fourth reservoir was begun, the claim being that the flow through a large reservoir would be at a low velocity, and that the sedimentation would be correspondingly good. This reservoir had a bottom laid out in the shape of a nest of very flat inverted pyramids, the bottoms being provided with valves, and a system of flushing sewers. The reservoir was 527 feet by 237 feet, with a depth of 47½ feet. The cost was about $200,000 and water was first pumped into it in 1855. This reservoir gave the city a great deal of trouble; the cleaning scheme proved a failure, and the walls required constant repair and careful watching. The water line was carried 138 feet above datum. This reservoir, after many vicissitudes, was finally abandoned and removed, and the site divided up, part being retained for public purposes and the remainder sold.

During the building of the new works, or from 1867 to 1872, a temporary reservoir on Gamble Street near Garrison Avenue was built and was used in conjunction with the old reservoir. In 1867 the sediment in the old reservoir was twenty feet deep.

The fifth pumping engine, with steam cylinder 30 inches diameter, stroke 10 feet, pump double-acting, piston 22 inches diameter, stroke 10 feet, was put in to keep up with the demand for water. In 1858 a new pump main 30 inches diameter was laid up Cass Avenue, and the 20 inch main was turned in on the distribution system. The old pumping engines, Nos. 2 and 3, were sold for scrap in 1857, and the Benton Street reservoir was abandoned in 1855.

At the old pumping station an engine with steam cylinder 34½ inches diameter by 10 feet stroke, and double-acting pump 28½ inches by 10 feet stroke, was put in to keep up the supply during the building of the new works (1865–72). This old station, with its pumps and piping, was operated until 1871, at which time the Bissell's Point Works started. A breakdown at this High Service Station necessitated starting the Bates Street engines again, but on June 19, 1871, they were shut down for the last time.

This station was wrecked and the machinery sold at auction, and after its removal the location was used for a pipe yard. The property was subsequently turned over to the Harbor Department for wharf purposes.

This is briefly the history of the St. Louis water works from the time of their inception up to 1867, for the old works; and up to 1871 for such temporary work in connection with the old works as was necessary during the building of the new works.

The new water works date from 1863, when the General Assembly

of this State passed an act entitled "An Act to enable the City of St. Louis to extend the Water Works thereof and for other purposes." This act authorized the city to construct works to take water from any point on the Mississippi River and conduct it to the city. It also created a board of four commissioners, to be elected by the Common Council of the city, to carry out the provisions of the act. It further provided for an issue of bonds for the purpose of constructing the new works, limiting the amount to $3,000,000.

The City Council, at its May session, 1864, passed Ordinance No. 5339, establishing and regulating the Board of Water Commissioners, in conformity with the general act of 1863. But, owing to general dissatisfaction, no action was taken under this ordinance, and, in January 1865, the General Assembly amended the Act of 1863, placing the appointment of the commissioners with the Governor of the State, who appointed Messrs. Dwight Durkee, Dr. Philip Weigel, N. C. Chapman and Stephen D. Barlow.

This board organized on March 18, 1865, and, on the 27th, submitted to the City Council the appointment of Jas. P. Kirkwood as Chief Engineer, which was approved.

On May 11, 1865, the Board directed the Chief Engineer to proceed with the surveys and plans for a system of water works. The plans and estimates were submitted on August 29, 1865, adopted by the Board October 6th and forwarded to the City Council for its action on October 12, 1865.

This scheme contemplated the location of the Low-Service works at the Chain of Rocks; the work to consist of a pumping station, settling basins and filter beds; the filtered water to be conducted by gravity flow in a conduit to Baden, and there pumped by the High-Service Plant to a reservoir to be built at Rinkels with a high water line 204 feet above datum; an auxiliary reservoir to be built on Compton Hill to furnish full supply for the southern part of the city. The works were designed for an ultimate capacity of 40,000,000 U. S. gallons per day. This scheme was rejected by the City Council in March, 1866. The Council recommended, after report by sub-committee, that the filter beds be abandoned and the works located at Bissell's Point.

During the consideration of this report by the Council, Mr. Kirkwood was sent to Europe to examine and report upon methods there in use for filtering water.

In April, 1866, the first Board of Commissioners resigned, and a second board was appointed. This board organized in August, 1866, with Geo. K. Budd as president and C. S. Solomon as secretary. In November of the same year it submitted to the Council plans for extending the old works, prepared by Freeman J. Homer, City Engineer.

In December, 1866, another plan was submitted, prepared by Mr. Kirkwood in accordance with the following:

Resolved.—That the Engineer be directed to prepare a general plan of works, founded on the following basis, to wit:

That the water be taken from the Mississippi River, in the neighborhood of Bissell's Point.

That settling basins be established there without the accompaniment of filtering works.

That a small storage reservoir be constructed on the City Commons.

And that the whole be arranged, so far as practicable, so as to admit hereafter of the convenient addition of whatever further works may then become expedient or necessary, and that the engineer be instructed to report the estimated cost of the works in question.

The plan reported by Mr. Kirkwood, in answer to the above resolution, is substantially the one upon which the new works were constructed.

In February, 1867, an ordinance looking to the enlargement of the old works and authorizing the issue of $275,000 in bonds, was passed. In March, 1867, the Board of Water Commissioners made a demand on the Comptroller for the bonds, appointed Mr. Homer superintendent, and instructed him to proceed to carry out the plan proposed by him in November, 1866. This scheme fell through and no work was done. The report and plans were printed in the second report of the Board of Water Commissioners.

On March 13, 1867, the General Assembly passed an Act authorizing the issue of bonds to the amount of $3,000,000 and appointing a new commission.

This commission, after it got into working shape, consisted of Geo. K. Budd, Alexander Crozier and Henry Flad, and under this board the works were built.

The Commission organized March 22, 1867, and on the 23d the former board turned over to them the old records belonging to the department.

On the 26th Mr. Kirkwood was requested to resume the duties of Chief Engineer from which he had been relieved by the former board on March 18th.

Mr. Kirkwood declined further service as Chief Engineer, and recommended Mr. Thos. J. Whitman for that position. Mr. Whitman reported for duty May 7, 1867.

Mr. Whitman was in favor of the Chain of Rocks location for the low-service works, adding his opinion to that of Mr. Kirkwood and all other engineers who had examined the situation carefully. He found, however, that the exigencies of the supply and the limitations of the law left but one thing to do, viz., to go ahead with the

work on the Bissell's Point plans. The works thus built, with which most of you are familiar, consist of an inlet tower, or intake, on the river bank at Bissell's Point; a low-service pumping plant; settling basins; a high-service plant; a stand pipe; large extensions to the old pipe system; and a storage reservoir on Compton Hill. These works, extended up to 1872 by the addition of two pumping engines, had a working capacity of about 32,000,000 U. S. gallons per twenty-four hours.

It must be borne in mind that all water furnished to the city is pumped twice; first, from the river into settling basins by the low-service plant; and second, from the basins into the distribution system and reservoir by the high-service plant.

In 1876, the city of St. Louis adopted a charter and changed its system of local government; the water works, with the exception of the collection of the revenue, being placed in the hands of a Water Commissioner, who acts as Chief Engineer and executive head of the department.

Additions to the high-service pumping plant were begun in 1881, and continued up to 1894. A new pumping station, complete, with pump mains and stand pipe being completed, making the total high-service capacity from 60–65,000,000 U. S. gallons per day (twenty-four hours).

To keep up the supply of water to the high-service plant, a temporary low-service plant was put in, having a capacity of 30,000,000 gallons per day. This plant, built on an inclined way, moves on wheels up and down the incline according to the stage of water in the river. The general scheme of this plant has been followed by the city of Cincinnati to afford temporary pumping facilities.

After several ineffectual attempts to secure the necessary legislation authorizing the extension of the low-service works, the City Council passed Ordinance No. 14212, approved September 7, 1887, establishing a low-service station at the Chain of Rocks. This station consists of an intake tower, an intake tunnel, a pumping plant and a system of settling basins.

The works are designed for a capacity of 100,000,000 U. S. gallons of settled water per day. Work on this plant is now nearing completion.

On December 26, 1893, Ordinance No. 17339 was approved, authorizing the further extension of the high-service plant.

The work on this plant has been started, but little, beyond the sub-foundation work, has been done. This plant is designed to furnish water to the districts of the city and county that lie at an elevation beyond the reach of the Bissell's Point works.

In closing, I will remark that it now seems that the city has got fairly to work along lines which, if followed, will insure to it an adequate supply of water, fulfilling all modern requirements.

II. Points of Interest in the Design and Construction.

By S. Bent Russell, Member of the Engineers' Club of St. Louis.

[Read March 21, 1894.]

In this paper I shall merely outline a few of the problems that were met in the engineering work, with the hope that they may prove of interest in connection with the other papers on the new water works.

Our first work was done on

THE NEW CONDUIT.

The two ends of our line were fixed at the old and new intakes. See Fig. 1.

Between these two points it was necessary to follow around a concave bend in the river so that the shorter line would, of course, be the closer to the bank. To secure the work in high water it was necessary to run the line along the edge of a terrace or berm known as the second bottom. As this conduit draws its water from the bottom of the new settling basins at the Chain of Rocks, and delivers it into the top of the old settling basins at Bissell's Point, there was not much choice in the matter of slope and elevation of the conduit.

The maximum flow line of the conduit is about four feet above the highest flood of the last twenty years and has a slope of 1 in 10,000, or about one-half foot per mile, which is somewhere near the slope of the Mississippi.

Near the old pumping works the line crosses low ground for nearly a mile, the masonry resting on a fill about five feet deep. There was some talk of using iron pipes over this stretch, but this idea was abandoned. A primary bank, raised to the elevation of the spring line of the conduit arch, was built and allowed to settle many months before placing the masonry and cover bank.

This primary bank rests on bottom land which is underlaid by quicksand some ten feet thick on top of the country rock. As soon as the cover bank was built its weight seemed to carry down the primary bank and masonry together. This settlement of the masonry amounted to from one to six inches, and was, I think, due to the displacement of the underlying quicksand; but that is a matter for discussion.

As the line crosses three important creeks, bridges were needed.

These were carried down to a rock foundation so that the conduit at these points is not allowed to settle.

THE CROSS-SECTION

of the conduit masonry is perhaps of special interest. In order that an empty tunnel in soft earth may have the greatest strength against distortion, its cross-section should be an ellipse with the major axis vertical. There are several practical objections, however, to making the height so great. We therefore cut the ellipse through the minor axis, remove the lower half and substitute an *inverted beam.* This bears the stresses in the arch the same as if the ellipse were complete. See Figs. 2 and 3.

If instead of the beam we had substituted a flat inverted arch resting on soft earth, the section would probably be somewhat distorted before the thrust of the inverted arch was balanced by the *passive* pressure of the earth behind the side walls.

As shown in Fig. 3, the section is only an approximation to a semi-ellipse, being made with vertical side walls and a full center arch. The bottom is designed to act as a beam, but is hollowed out in segmental form, as this gives an increased water way at slight expense. The outside of the side wall was carried up vertically so that the concrete might rest against the undisturbed earth in the walls of the trench.

About seven-eighths of the line was in cut. The conduit was everywhere covered with three feet of earth. All railroad crossings are bridged over so as not to rest on the masonry or cover bank.

Overflow weirs are provided at distances of about two miles. Manholes are about one-fourth of a mile apart. Large chambers are arranged at each end and at each change of water section, so that cleaning machines can be put in, floated down and removed without difficulty. To permit this, there are, of course, no obstructions allowed in the waterway, which remains of the same form from end to end of the 11-foot conduit, and from end to end of the 9-foot conduit.

Before proceeding further with the plant itself, let us take up the subject of

ORGANIZATION

and methods of the engineer corps. The civil engineering force included four divisions: the conduit division, the river-work division, the basin division and the drafting division. Excepting the last-named, each division was composed of a division engineer, a field party and inspectors of contract work. There were three offices—one at Bissell's Point, one at the Chain of Rocks, and one, half way between these, at Baden. Each party was provided with teams for transportation.

To prepare for construction, preliminary surveys were made for

each piece of work. Frequent soundings and borings were made, to determine the elevation of the rock. Our experience taught that the evidence obtained from borings must be used with discretion. What is reported to be bed-rock often proves at a later date to be but a lonesome boulder. In important cases, therefore, trial shafts were sunk before the contracts were let.

To comply with the law, all important construction was done by contract let to the

LOWEST BIDDER.

Hence to obtain good work it was necessary to have the plans and specifications very full and complete. Our contracts might be divided into two general classes—*A*, where a lump bid is made for the whole work; *B*, where a bidder names a price per unit of measurement for each class of work and the value of the bid is determined by the engineer's estimate of quantities. Form *A* was generally used for machinery, buildings, etc., and Form *B* for earth and rock work, masonry, pipe lines, railroad tracks, etc.

When form *A* was used the greatest care was necessary in the preparation of plans and details, as alterations of plans generally caused extra expense to the city. Any losses caused by errors in these plans were borne by the city.

SPECIFICATIONS

were first drafted by the engineer of the division, checked over in the drafting department and revised by the principal assistant engineer. They were then submitted to the Water Commissioner, and by him laid before the Board of Public Improvements.

PLANS

were made by the draftsmen, checked over by the first draftsman and then by the engineer of the division including the work. They had then to be approved in order by the principal Assistant Engineer, the Water Commissioner and the Board.

All drawings are numbered and indexed in a card catalogue of the kind used for libraries. We have, I think, about 1,400 drawings catalogued. Field notes too are numbered and indexed in the same catalogue with the drawings.

In preparing our contracts, we endeavored to divide between the two parties to the contract the risks of unforeseen difficulties. We thus on the one hand avoided excessive prices due to contractor's risk, and on the other hand made it the contractor's interest to keep down the cost of the work.

After the contract was let, the only

SECURITY

the city had, was in the bond of the contractor. By retaining a percentage on monthly payments the security was gradually increased until the work was completed.

Under the law, the Board of Public Improvements can take no account of an individual contractor's actions in the past, and this condition has added considerably to the difficulty of obtaining good work. In the

EXECUTION OF CONTRACTS

rigid inspection was the rule. Inspectors were frequently located at shops, mills, quarries, etc. In the field, wherever a foreman was needed, there would be an inspector. All water-tight work and underground work was given special attention. From our system of letting contracts there was necessarily no consideration shown a contractor on account of low prices.

Effort was made to keep accurate accounts of all force and material used by the contractor.

Materials were tested when practicable. As the item of cost of cement was in the hundred thousands, especial attention was given to the tests of this material.

When a piece of work was completed

FINAL DRAWINGS

were made, showing it as actually built in detail, while records are kept showing all tests of material used, etc.

We will now return to the plant itself, taking up the

INTAKE AND PUMPING STATION.

The first work done was in making soundings of the river and borings in the shore, preliminary to designing the plant. Submarine borings in the rock were desirable, but were omitted as being too expensive. Before finally deciding on a tunnel, a prospect shaft, 90 feet deep, was sunk on the proposed line. This was accomplished with considerable difficulty, owing to the water encountered.

The problem of designing the intake was an interesting one. The low water channel was found about 1,500 feet from the shore. Between it and the river bank is bare rock bottom, showing projecting reefs at low water. The difficulties in the way of laying a pipe out to the channel were great. It was thought wiser to tunnel under the river.

The intake tower offered some interesting problems. Such a tower, with its gates, screens, etc., is by no means as easy to build in twenty

feet of water as a bridge pier would be. A masonry tower was decided on, and a suitable site on the rough rock bottom was selected by careful soundings. The tunnel was kept as near to the bottom of the river as was thought safe, so that in case of necessity compressed air could be used to check the inflow of water.

The question of lining the tunnel was discussed. While it was driven through solid rock and would not need any support, the large amount of sediment in the water to be taken, made a uniform and high velocity of flow quite necessary to prevent an excessive formation of sand bars. The section adopted is a circle 7 feet diameter inside of the lining. This will give 100 millions of gallons in twenty-four hours, with a velocity of about 4 feet per second. In case the tunnel becomes obstructed, it can be drained and cleaned. Both the river and the shore ends of the tunnel drain to a sump in a shaft on the river bank, and a short branch tunnel, controlled by a gate, taps this sump and drains to a large shaft in which pumps may be set.

There was some discussion as to the best location for screens to intercept the fibre in the water. Coarse gratings were put over the tower gates to stop large drift, but the fine screens were put in a chamber at the outflow end of the tunnel near the engine house, where they can be watched and frequently cleaned.

We started the tunnel under the river from the shore shaft on a rising grade of 1 in 200. For the first 600 feet our grade followed very closely the stratification of the limestone. Then the roof rock began to dip rapidly the other way. To keep to our plans we would have had to cut through this stratum. There were, however, indications of a wet seam above this layer of rock, and it was thought prudent to follow the trend of the rock. We did this, driving a 7 x 10 foot heading until we had nearly reached the end, when the rock dipped so rapidly that we were forced to cut through the roof layer. It was not until our heading was driven the entire length that we laid out the final grade for the brick lining. It was then decided to lower the axis of the lining so as to avoid cutting into the roof rock except at the channel end of the tunnel. This change of grade was quite expensive, but to have avoided it might have proved much more costly.

Although we stopped off large quantities of water in our working shaft, we still had a steady downpour of 50 or 60 gallons per minute in the shaft while we were driving the tunnel. About 1000 feet from the shore we crossed a fissure that poured about the same amount of water into the tunnel. There was a little seepage all along the line. The water gave us considerable trouble in lining the tunnel. At the fissure above mentioned, where there was a sheet of water pouring through the roof right across the tunnel, we prepared for the brick lining by putting in a

wrought iron shield curved to 54-inch radius, and provided with gutters and spouts to lead off the water. This shield was hoisted into position under the cataract and the brick arch carried through underneath it, leaving the shield concealed in the brick work.

In lining the tunnel we worked down the grade. Short pipes were laid through the wall where needed to relieve springs of water. When we had a long stretch of tunnel lined, and the water running along the invert had become troublesome, we built across the tunnel a brick dam provided at the base with a 6-inch outlet pipe and valve. Before starting a length of invert the valve was closed and the seepage allowed to accumulate above the dam. When the stretch of invert was ready, and the upper end of the tunnel was full of water to the top of the dam, the valve was opened and our reservoir emptied out. Two of these dams were built, and they proved very useful in storing the seepage water until it could be released without inconvenience.

IN DESIGNING THE INLET TOWER

at the channel end of the tunnel, account was taken of the enormous strains which might result from ice gorges resting on and wedging against the structure.

As a small base was desirable on account of the expense and difficulty of placing a large coffer-dam, the superstructure was given additional height and weight to increase the stability.

To increase the resistance against shearing, large anchor bolts were set, passing through the lower five courses of masonry, and reaching several feet into the rock ledge. As shown in Fig. 6, the up-stream end of the tower is formed into an ice-breaker. On account of the wide range in the stages of the river, gates were provided at different levels. At high water the lower gates will remain closed, and those which are more accessible will be used. The gates in the north chamber will generally be used, as, in case of their failure to shut, the gate in the party wall can be used to keep the water out of the tunnel.

The shore end of the tunnel empties through the screen chamber into the

WET WELL

from which the pumping engines draw.

In locating this part of the work, after sinking many bore holes and prospect shafts, it was found best to build at a point about 700 feet inshore, where the excavation would be in more stable material. In the design of this plant the flood height of the river was again a factor. The engine pits, etc., must be proof against high water, and on the other hand the pumps must be little, if any, above the low water level. Hori-

zontal pumps would not seem appropriate under these conditions, and hence deep pits and vertical pumping engines had to be adopted.

The conditions of the pumping problem were these. The water must be delivered at a fixed elevation, to supply the settling basins. It must be drawn from an elevation depending upon the stage of the river.

There is some controversy as to the best arrangement for such a case, some contending that the water should be held back by means of gates, so that the pump will work under a constant suction lift, while others would allow the pressure in the suction to vary with the stage of the river so as to reduce the average lift. At the Chain of Rocks the pits and gates have been so arranged as to permit the use of either method. A wet well or fore bay is provided, in which the water may be allowed to stand at the level of the water in the channel of the river, or may be kept at the constant level of low water. Before the cheapest and best form of wet well could be agreed upon, it was necessary to consider whether the well should be built as part of the same structure as the engine pits, with only a masonry dam between them, or whether it was better to use a separate structure, as was finally adopted; whether the well should be rectangular or circular; whether there should be one or several, and whether it or they should be large or small.

In getting out the details, the design of

THE RETAINING WALLS

formed an interesting study. Allowance was made for the support given by cross-walls. Part of the overturning moment is balanced by the transverse strength of the masonry. In preparing the plan of the engine house we were limited by the great depth of the substructure. A rectangular building was inevitable, if we would have a solid foundation.

It was thought safer also to have the boiler-house independent on its own foundations, so that it might settle without distortion.

The delivery well, into which the engines pump, was located on rising ground in front of the pumping station where there was a good clay foundation for the masonry. Each engine is provided with an independent delivery pipe which spills into this basin. A free spill was given so that there can be no return flow when a pump is stopped.

THE BOILER HOUSE

was planned for a single row of boilers, as this arrangement is best for ventilation and light. The chimney, 6 x 150 feet in interior dimensions, is of brick. It stands on a separate foundation extending to ledge rock. Flues and steam mains are overhead. Considerable effort was made to

find an economical way of getting the coal from the railroad train into the furnace. What might be called the reservoir system was finally adopted, on the ground that it would be the most uniform in operation. By this plan all coal must be handled three times.

From the gondola car it is unloaded into the coal house. It is then shoveled, as needed, into iron charging cars, and from these into the furnace. The coal-house forms a reservoir so that the contractor can unload his cars as they come in, while on the other hand the coal passer has always about the same distance to go for his coal. This method gives a much more sightly stoking-room than is had where the coal is delivered directly in front of the boilers.

BUILDINGS

were made rectangular in plan, with tin roofs. The engine and boiler-houses were built with riveted steel roof trusses.

TRACKS

for coal-car handling were laid out with some care. There is a siding for loaded trains and one for empties. Another siding runs through a long coal shed for reserve coal, to be used only in case of strikes or other emergencies. A siding runs into the machine shop, and another runs into the engine house, so that machinery can readily be moved from one building to the other. Two forty-foot track scales are provided for weighing cars.

THE SETTLING BASINS

offered many interesting problems, and it will be hard to give a readable list of them in the short space which I have allowed myself. The first and most important question that came up was whether the basins should be designed for a uniform continuous flow of water or whether the water should be allowed to come to rest and be given a period of undisturbed settlement before it is drawn off into the conduit leading to the high-service pumps. By which plan should we get the best results with a given expenditure?

The difficulties in the way of arriving at the truth in this question were considerable. There was no way of comparing the two methods, on a large scale under similar conditions of sediment, etc.

A basin designed for the plan of quiet settlement or of *filling and drawing*, could not easily be altered so as to use the continuous flow system to the best advantage.

Each scheme has its advantages and its drawbacks, so that it is not merely a question of volume or area or amount of masonry. Inlets and outlets must be considered. Constant flow basins usually receive and

deliver their waters over long shallow weirs. They may be built with paved sloping banks. Basins which are drawn off at short intervals must have vertical walls, as the mud would settle on the slopes and in the drawing would be exposed or would slide down. In the matter of banks, therefore, the constant flow basin would be cheaper. The best form for a continuous flow basin is hard to determine. Some think that the water should flow over many weirs; but others dispute this. The filling and drawing plan offers the greater elasticity in operation, as the basins may be gradually drawn down in case of need without seriously interfering with their operation. We thus take advantage of their storage capacity, to prevent a shortage of water in case of accident to our pumping machinery.

The old basins at Bissell's Point were designed for filling and drawing and have given good results. As the water in the river, however, is never twice alike, it would be hard to get scientific expressions of the clearing obtained.

After thoroughly sifting the testimony, the evidence seemed to be stronger on the side of the quiet settlement plan. The following are some of the arguments which would seem in

THEORY

to support this conclusion.

It is very difficult to add water to a vessel containing still water without disturbing the latter.

Any one can learn this by trial. Take a glass of still water containing light sediment at the bottom, and try to add water to the glass without disturbing the sediment at the bottom. On the other hand it is easy to draw water out of a vessel without disturbance. One can readily decant or siphon water out of a glass and yet leave the sediment at the bottom. Now the kinetic energy introduced in filling a basin must be absorbed in friction, and the internal friction of liquids decreases with the velocities of the currents, so that it takes a long time to use up *all* of the energy in this way.

In flowing water the particles never move in parallel straight lines. In the case of water flowing through a cylindrical pipe it is probable that each particle of water is always moving in a curved path, that is, each group of particles always has some angular velocity. The paths of the particles may be likened to the fibres in a rope which have something of the form of a compound helix. Each fibre is twisted around the other fibres of the strand while the strand is twisted around the other strands. It is only by some such system of compound curves that the observed phenomena of flowing water can be explained. Water flowing into or through a reservoir must break up into currents or masses, each mass having both linear and angular velocity.

2

It is by means of these angular velocities that flowing streams are enabled to sustain solid matter. The swifter the stream, the greater the angular velocities in a vertical plane, and hence the greater is the carrying power.

Let us imagine a cylinder with horizontal axis filled with jelly or similar material. In the jelly is a leaden weight. While the cylinder is at rest the weight sinks with a uniform velocity m. Now revolve the cylinder with a uniform angular velocity a. The weight will tend to describe a circle not concentric with the cylinder. If we eliminate the effect of inertia, the body will move in a closed path and will never sink below a certain level as long as the angular velocity remains unchanged. Hence, with a given depth of water and a given angular velocity, sedimentary particles of a certain limiting size will subside, while those a degree finer will be held in suspension.*

Applying these theories to the clearing of water, we see that the aim must be to reduce to a minimum the angular velocities in the water. If we could suddenly bring a body of muddy water to a state of absolute rest the water would become clear in a remarkably short space of time.

In a constant flow basin the slower the movement of the water the faster it will clear. With a given volume of basin the best result should be obtained by stopping all flow for a time, as is done in the system of filling and drawing. As soon as the inflow of water ceases the internal velocities begin to decrease, rapidly at first but at a diminishing rate. The finer and lighter the sediment, the longer it will take to reduce the velocity of internal currents to the clearing point. A slight decrease in the size of the grain makes a great increase in the time required for settlement.

After having decided on using the fill-and-draw system we took up the question of

THE NUMBER AND SIZE OF THE BASINS.

Taking twenty-four hours as the time of settlement, we used the following expression to denote the working capacity of a set of n basins holding q gallons each:

$$(n - 1\tfrac{1}{2})\, q.$$

That is, we consider that while a basin is being filled, no settling will take place, and that the settling during drawing is equivalent to one-half that of a full basin for the same period. Observations made in our old basins show that the water continued to improve as the basin is being drawn off.

* For discussion of this principle see paper by J. A. Seddon, in JOURNAL OF ASSOCIATION OF ENGINEERING SOCIETIES, Vol. VIII, 1889.

In the new plant, just completed, Fig. 4, we have six basins of 22,000,000 drawing capacity each. By the formula, this gives, for the system, a working capacity of 99,000,000 gallons every twenty-four hours, with twenty-four hours' settlement.

Six to eight basins would seem to be the economical number for our conditions.

It is believed that with a given *volume*, the depth of the basin does not affect the time of clearing.

The economical depth would be that which, with a given expenditure, would hold the greatest volume. It was feared, however, that water less than twelve feet deep might spoil in hot weather, and hence the actual depth was made greater than the computed economical depth.

While not so direct in plan, it was thought wiser to bring the water to the basins on the west side, which is away from the river, as this location puts the *filling conduit* on higher ground, so that it can be built of masonry. The water is drawn from the basins at the side towards the river, as the basins are some six feet deeper at this side. The drawing gates are placed at the very deepest part of the basin, just over the mud-gate which opens into the sewer.

It was thought unnecessary to provide drawing-gates at different levels, as was done in the old Bissell's Point plant; for the water has been shown to be of practically equal clearness at all depths after a few hours' settling.

Connections between the basins and the drawing and filling conduits were made with 60-inch cast iron-pipe, laid in five-foot lengths, with lead socket joints. Allowance was thus made for unequal settlement in the basin walls and conduits, as the lead joints will allow some movement without leakage.

The six basins are as nearly identical in form as they could be built. Each basin has independent connecting pipes and gates, and each basin has an independent flushing sewer to the river.

FOR FURTHER INFORMATION

regarding the general features and details of the plant in question, the reader is referred to the illustrated and descriptive articles in the following journals. In these he will find much that must be understood in the discussion of the points I have outlined, but which, in order to save space, I have omitted to repeat:

The *Engineering Record* for 1892 containst he following series of articles on the St. Louis Water Works Extension:

I. General description of conditions, maps, general elevations and details of inlet tower and gate house, and description of coffer-dam. April 9, 1892.

II. Hydraulic cylinders in gate-house, details of gates, frames and racks. April 16, 1892.

III. Inlet tunnel and shafts. May 7, 1892.

IV. Wet well, screen chamber, engine-house foundation and delivery well. May 21, 1892.

V. Settling basins, and filling and drawing chambers for same. August 6, 1892.

VI. Sections of 11-foot and 9-foot conduits. August 13, 1892.

VII. Maline Creek Aqueduct Bridge. September 3, 1892.

VIII. Culverts under conduit. September 17, 1892.

IX. Terminal chamber of conduit and connections. October 22, 1892.

X. Construction of masonry conduit. November 12, 1892.

The *Engineering News* has published the following articles:

Settling basins and details. April 18, 1891.

Inlet tower and tunnel. July 4, 1891.

Brick chimney. July 26, 1891.

III. New Machinery.

By John A. Laird, Member of Engineers' Club of St. Louis. *

[Read April 4, 1894.]

In this paper on the New Machinery for the St Louis Water Works, the writer will give a short description of the different engines under contract, with some details of specifications, lettings, prices, steam connections and proposed system of operating and maintaining. He also hopes to be able at some future time to give the Club some information respecting the duty trials of the different types of engines.

The Water Department has now under contract seven pumping engines of four different types. Their aggregate cost with the boilers will be in the neighborhood of \$800,000. High-service engine No. 6 is a single cylinder, low pressure condensing beam engine of about 16 million gallons daily capacity. It is being built by the Southwark Foundry and Machine Co., of Philadelphia, at a cost of \$110,500.

The first pair of engines for the Chain of Rocks low-service station are compound condensing duplex of 20 million capacity each. They are being built by H. R. Worthington, and will cost, in round numbers, \$300,000.

The second pair of engines for Chain of Rocks are compound condensing engines of 30 million capacity each. They are being built by the Edw. P. Allis Company, at a cost of \$156,000. Finally, the two

Baden high-service engines are three cylinder, triple expansion condensing engines of 10 million gallons daily capacity each. They are also being built by the Allis Company. They will cost $132,000, and undoubtedly will represent the very latest and best steam practice.

The contracts were all let to the lowest bidders, according to the usual method of letting city work.

High-service engine No. 6 is of the old beam and fly-wheel type which has served the department so well for the past twenty-four years. There were three bidders at the letting:

Fulton Iron Works	$128,000
Holly Manufacturing Co.	119,000
and Southwark F. & M. Co.	110,500

The contract was awarded to the Southwark Company, and the machine is now being erected in place at Bissell's Point. The indications are that she will be ready for steam about the middle of June. There is very little of special interest in this engine. The main shaft is of nickel-steel, and is the first piece of that remarkable alloy, of any size, which has come to St. Louis. It was made by the Bethlehem Iron Company, and was forged entirely by hydraulic pressure, with a 7-inch hole through the center, and tempered in oil. Test specimens cut out of each end of the finished forging showed a tensile strength of 92,000 pounds, and an elongation 22 per cent. in 4 diameters.

The first bids for engines to be placed at the Chain of Rocks were opened in July, 1890. The specifications did not call for two engines of 20 million gallons daily capacity, but for two engines capable of delivering 600 million gallons in 720 consecutive hours. It is quite unnecessary to say anything on the relative merits of the designs proposed at the letting, as the subject was very well aired at the time. There were three bids presented, as follows:

Builders' Iron Foundry.	$342,000
Holly Manufacturing Co.	314,000
Henry R. Worthington	299,500

The contract was awarded to the Worthington Company, and the engines are now erected in place at the Chain of Rocks. They are compound duplex condensing engines, with the Worthington high-duty attachment. Each engine has two high pressure and two low pressure steam cylinders, which are respectively 21 and 42 inches in diameter, and four single acting plungers 36 inches in diameter, and under each steam cylinder, all of 80 inches stroke. The engines are balanced by means of walking beams, at the ends of which are placed the oscillating cylinders of the high-duty attachment. The beams are built up of

two diamond-shaped steel plates 1 inch thick, separated 14 inches by cast-iron distance pieces. This, although very weak laterally, is strong and light as a beam. As all of the work is done while the plungers are going down, the beam will always be transmitting the work being done in one cylinder, and this effort will be a pull, tending to raise the beam in the bearings. These machines are 70 feet high, and they stand in the middle pit, which is 50 feet square. There is no masonry foundation, the bed plates resting on the pit bottom, and no connection to the walls except by gangways. The pit is not floored over, and all galleries, stairways and landings are of open work as on marine engines. This allows light to penetrate to the bottom of the pit, and the engineer, standing on the upper gallery, can see clear to the bottom. There is no need of artificial light in the daytime anywhere about the pumps, except inside of them. The joint between bedplates and pit bottom is from $\frac{1}{2}$ to $\frac{3}{4}$ of an inch thick. It was made by grouting with Portland cement. The foundation bolts were also grouted in, and, after the cement was set, we were not able to produce any perceptible movement by hauling down hard on the sixteen $2\frac{1}{2}$-inch foundation bolts.

There is a surface condenser in the delivery pipe, and an independent jet condenser for emergency. The other parts of the engine do not differ materially from those of the well-known Worthington type. In building the Chain of Rocks engine-house the Water Commissioner departed from the time-honored custom of allowing the contractor to use any means which might be at his disposal for erecting the engines, and installed a 15-ton electric traveling crane, capable of sweeping the entire engine-house and having a vertical hoist of 80 feet on the blocks. This crane would also furnish material for a paper, and I will say that it is almost a thing of beauty, and that it has been a joy up to date. It is the first complete power crane which has been placed in a pumping station, and I know of only one crane which has a greater hoist of block. On the day upon which it was turned over to the Worthington Company, they lowered 150,000 pounds of bed-plate 60 feet into position in the pit. Almost any one can design a crane that will *hoist* a given load, but it takes extraordinary capacity to design one which will *lower* the load with perfect satisfaction. This crane has not caused a moment's delay since it was turned over to the contractor, although it has been looked after and operated by an ordinary helper, who had to be taught how to run it.

In the old stations all of the boilers deliver their steam into one great main, to which all of the engines are connected. At the Chain of Rocks there will be three batteries of boilers and three pairs of engines, with a separate steam main connecting each battery of boilers to a pair of engines. In addition to the main connection we have by-

passes by means of which steam can be taken from any boiler for any engine in case of emergency.

The C. W. Hunt system of tracks, charging cars and ash cars, which is in use at Bissell's Point, will be used at Chain of Rocks. Track scales are provided for weighing coal and ashes, and all of the feed water will be metered. This gives an opportunity to compare the duties of different types of engines running in the same house and on the same work; in fact, to make the running of the engines and boilers a perpetual duty trial. The duty required by the specifications is 85,000,000 foot-pounds of work per 1,000 pounds of commercially dry steam, correction being made for entrainment above 3 per cent. Both capacity and duty trials are for 720 consecutive hours.

The two engines under contract by the Allis Company, for the North Pit at Chain of Rocks, are each to pump 900 million gallons in 720 consecutive hours, and are the largest in the department. The letting took place in November last, and there were five bidders, as follows:

Holly Manufacturing Co.	$287,000
H. R. Worthington	220,000
Southwark F. & M. Co.	203,000
Rankin & Fritsch	193,000
Edw. P. Allis Co.	156,000

The contract was awarded to the Allis Company, and work has been begun on them in their shops. The machines are vertical cross compound, with surface condensers and fly-wheels. The steam cylinders are 28 and 54 inches in diameter. Each engine has two single acting plungers 48 inches in diameter; all 108 inches stroke. If the well-known Reynold's triple expansion pumping engines were to be relieved of one cylinder, one fly-wheel and one pump, the result would be the Chain of Rocks type. These machines, like the Worthington's, will rest on the bottom of the pit and will have no masonry foundations. The duty required is 100 million on a thirty days' test.

The bonus, amounting to about $375 per million, offered by the city in the specifications for the first pair of engines, as a reward for superior efficiency, cut no figure whatever in the bidding. In writing the specifications for the first pair of Baden engines it was proposed to improve upon this. The duty required was 125 foot-pounds per 1,000 pounds of dry steam on a twenty-four hour test. The bonus offered was in the ratio of $1,000 for each million foot-pounds of above 125. Almost any builder of modern pumping machinery will claim a duty of at least 140 millions upon his particular type of machine, and the idea was to give these men a chance to put up their hard-earned dollars for the purpose of corroborating their oft-repeated statements. The result of the letting

was a surprise to every one connected with it. There were six bidders for the two engines, as follows:

Groschon High Duty Pumping Engine Co. .	$223,000
Southwark Foundry and Machine Co. . .	220,300
Holly Manufacturing Co.	198,000
Rankin & Fritsch	173,000
H. R. Worthington	155,000
The Edw. P. Allis Co.	132,000

As a matter of course, the contract was awarded to the Allis Company, and they have begun work on the machines in their shops.

The specifications called for two triple expansion pumping engines of 10 million gallons daily capacity each, to pump against a pressure of 125 pounds, with 125 pounds steam pressure. They will be located in the high-service station No. 3 at Baden. They are of the well-known Reynold's type of vertical triple expansion engines. The steam cylinders 31, 56 and 80 inches diameter respectively, the plungers are single acting, 25½ inches diameter and all are of 64 inches stroke. Each engine has two reheaters, and all the cylinders are jacketed; the high-pressure cylinders with live steam, and the intermediate and low-pressure cylinders with steam at reduced pressure. They are provided with surface condensers, and the air and boiler feed pumps are connected to the low-pressure plunger head. All of the plungers are so loaded that the steam will have to do the same work in lifting the plungers and its connections on the up stroke as in going down and forcing the water. The Reynold's Corliss valve motion is used and Corliss valves are set in the cylinder heads. This brings the clearance spaces down to a minimum. On the high-pressure and intermediate cylinders the percentage of clearance is less than 1½, and on the low pressure less than half of 1 per cent. This is as low as it would seem possible to make it and helps to account for the splendid duty shown by this type of engine. The one feature which distinguishes these machines from all other pumping engines of this size, is the pressure relief valves, which are designed so that a gate in the discharge pipe can suddenly be closed while an engine is running at full speed, in which event all of the water would be by-passed back into the suction pipe. As these pumps will deliver into what is practically a closed system, some such device would seem to be necessary. In starting up, the load may be taken off the relief valves and the engine started slowly, churning the water through the by-pass. Gradually increasing the load on the relief valves, the long column of water may be started very slowly. When the load is increased to the point when no water comes through the by-pass, the pump will have its full load, and any sudden increase in pressure will only cause the relief valves to open proportionately.

On the other hand, the engines are provided with regulators to prevent racing, and if a break in the main should take off all the load, the regulator would stop the engine. If these appliances satisfactorily fill the requirements of the specifications, the machine will be admirably adapted to the very hard service for which they are designed. The plant will be arranged substantially as the one at the Chain, and it is proposed to use a 20-ton electric traveling crane.

It would be very interesting to analyze the various designs which have been submitted at the different lettings and come to some definite conclusion as to the real reason for the great difference in the prices asked by responsible builders on the same specifications. Taking even the three lettings, the machines are nearly all the same weight, and it is difficult to see why the prices vary from $342,000 to $132,000; and, in one letting, from $287,000 to $156,000. It was evident on the face of the bids at the Baden letting, that the Allis Company was the only one that had sufficient confidence in its machine to pay any attention to the bonus clause. So far as the other builders were concerned, that clause might have been struck out. Worthington's design was the lightest and the cheapest, and, but for the bonus, would have taken the contract. But 125 millions is a high duty for that type of engine, and the bidders could not feel safe in cutting their price when there was a possibility of paying a forfeit at the rate of $2,500 per million, that the duty fell below 125.

Rankin & Fritsch made a good, fair bid upon a design by Mr. F. W. Dean, of Boston, figured very carefully down to the lowest living price. The design did not differ materially from the Allis engine, and the engine would have been of nearly the same weight. But these bidders were handicapped in two ways. The design would have cost them at least $10,000, and never having built an engine of this class, they would not have been justified in making a guarantee of more than the 125 million duty required. Taking $10,000 from the bid for the design, leaves $163,000 for two machines, or $81,500 each. There were several reasons for the high bid of the Southwark Foundry and Machine Company. In the first place they spared no pains in getting up the design, but made it the very best they knew how. Their machine was also much heavier than any of the others. Its total weight was about 2,300,000 pounds, while the Allis, and Rankin & Fritsch engines weighed only about 2,000,000 pounds each. Southwark's price per pound was 9.5 cents, and Allis' 6.6 cents, but, adding the $30,000 which they expect from the bonus, we get 8.1 cents; while the $50,000 bonus which they may succeed in getting, makes their bid 9.1 cents, which is not so far from Southwark's price. The Allis Company figured on doing 140 million duty, and cut their bid accordingly. This duty

would bring them $30,000 on both machines, and this, added to their bid, brings it to $162,000, or $81,000 for each engine, which is remarkably close to what Ranken & Fritsch figured for building the Dean machine These figures look very low in comparison with the price paid for the Worthington engines. They weigh 1,675,000 pounds, and the contract price is $299.500, making the price per pound 18¼ cents. Of course these are only very rough comparisons, but they show plainly that the city paid an enormons price for the first two machines. Part of the difference between this and the cost of the later engines is due to reduction in the cost of material. It almost seems that in the short time intervening between the first and the last letting, pumping machinery of this class has passed from a stage when it is built to that of being manufactured.

It is very interesting to note the change which has taken place in pumping engine design in a little over three years. At the letting in 1890 all designs were for beam engines. In 1893 Worthington was the only pumping engine builder in the country who cared to bid on a beam engine. As imitation is counted the sincerest flattery, Edwin Reynolds must feel very highly complimented, for all but one of the great pump builders in this country are paying tribute to the genius of the man who designed and built the first triple expansion pumping engine in America, by substantially copying his design of marine engine applied to pumping engine practice.

The North Point engine at Milwaukee designed under the general supervision of Mr. Reynolds, with a duty of 154 million foot-pounds per 1000 pounds of dry steam, and an indicated horse-power per hour on 11.6 pounds of dry steam, holds the world record for economy in steam using.

When the Chain of Rocks and Baden stations are completed, the works will be able to furnish 100 million gallons daily with only about two-thirds of each plant in operation. Then it is proposed to put the machines on regular watches like the men, only the engines will work two-thirds of the time, and the men one-third; while the engines are resting they will be given a thorough overhauling, as marine engines are given while they are in port. This will add to their life, and it is hoped that it will show an increase in the economy of the machines. When an engine has stood a run of say two weeks, she will be shut down, and one of the crews which has been running, will open up the pump, take off the cylinder-heads, examine all packing, bearings and valves, make all adjustments, and in short give the machine an overhauling similar to what the builders give just before running a duty trial. While this is going on in the engine room, another crew will open up the boilers, give them a thorough cleaning, renew grates and other parts requiring renewal,

examine all valves, fittings and distribution pipe, and put the boilers in exactly the condition which the boilermaker would put them in when preparing for a duty test. By this means the entire plant will be kept constantly tuned up to concert pitch. Whenever an engine is started up after being overhauled, steam cards will be taken from all of the cylinders to see that everything about the valve motion is in adjustment.

By means of a complete set of log books, the duty performed by every engine or battery of boilers on any watch may be laid before the chief engineer. This gives a check, not only on the duty that the engines are doing, but on the work of the men, and the fireman who does his work conscientiously and gets a high rate of evaporation, will be paid more than the one who just manages to make steam enough to keep the engines going. It will also be known, by the duty the machines give, how well the crew does its work in overhauling and tuning them up. With a system something like this it will be possible to elevate the grade of work in all departments, and to educate the firemen to be something more than mere coal-heavers. Why should the city spend one and a quarter million dollars for new machinery of the latest high-duty type and not have the very highest grade of work procurable in the fire-room as well as in the engine-room? The maximum efficiency will not be reached in a month, or perhaps in a year, but by giving the men substantial proof that they are paid to use their heads as well as their hands, we shall, in a comparatively short time, have in charge of of the new machinery a corps of men as much more efficient than the old crews as the new engines are better than the old ones.

This leads naturally to the question as to how much saving can reasonably be expected from the use of the high-duty engines; as to the duty obtained from the old engines, no careful duty trial has been made, so far as I know. Reducing to duty the quantity of coal burned, the high service engines give a little over 30,000,000 foot-pounds per 100 pounds of coal. Assuming five pounds evaporation, which is a little low, we get 65,000,000 on a 10-pound basis. Or, reduced to steam per horse-power per hour, we get something near thirty pounds.

As to what may be expected of the new engines, I will consider only the high service, as the ratio of duties between the new and the old low service engines will be as high as corresponding ratios on the high service.

It would not be safe to take results of twenty-four-hour duty trials as a basis of computation, and the only figures I have at hand for comparison, which are worth considering, were given me by Mr. Benzenberg, City Engineer of Milwaukee. He says that the North Point engine, which is very similar to our Baden machine, designed by the

same man and built by the same company, gives a monthly duty of 120,000,000 foot-pounds per 100 pounds of coal, without any deductions. The coal used is anthracite, and gives about 8¾ pounds evaporation. This brings the monthly duty up to 136,000,000 on a 10-pound basis. Can we reasonably expect as high results on the Baden engines? It would seem so. The water pressure is higher, the steam pressure a little higher, and the clearance spaces on all the cylinders a little less. Surely it would not be out of the way to expect 130,000,000 on a 10-pound basis. Granting this, the coal bill will be reduced one-half, as also the cost of coal-passing and firing, and one engineer will run two engines. But the item of wages will cut very little figure, for a certain number of men must be employed in connection with a plant of this size. Let us suppose we do the same work and save half of the coal. One of the old 15,000,000 engines takes fifteen tons of coal to a watch of eight hours. They will run two-thirds of the time, or two watches a day, through the year.

Then, on a 15,000,000 gallon engine, we would save fifteen tons per day, or 5,475 tons per year. At the present contract price for coal, this amounts to $7,150—quite a respectable sum—which, capitalized at 5 per cent., gives $143,000, which would more than build a high-duty engine of equal capacity.

I have gone very hastily over the subject of the new machinery for the water-works. As most of the work remains to be done and none of the engines have been started, I have only been able to tell what we proposed to do and give the results we hoped to obtain. There will be material for several papers of very high scientific as well as practical value on the duty trials of the several machines. The water commissioner intends having all tests conducted by experts of acknowledged ability and experience in this class of work. Mr. C. C. Worthington, in speaking to the writer about the proposed tests, said that he would consider the reports of the same, if made under the general supervision of Mr. Holman, a most valuable addition to pumping-engine literature.

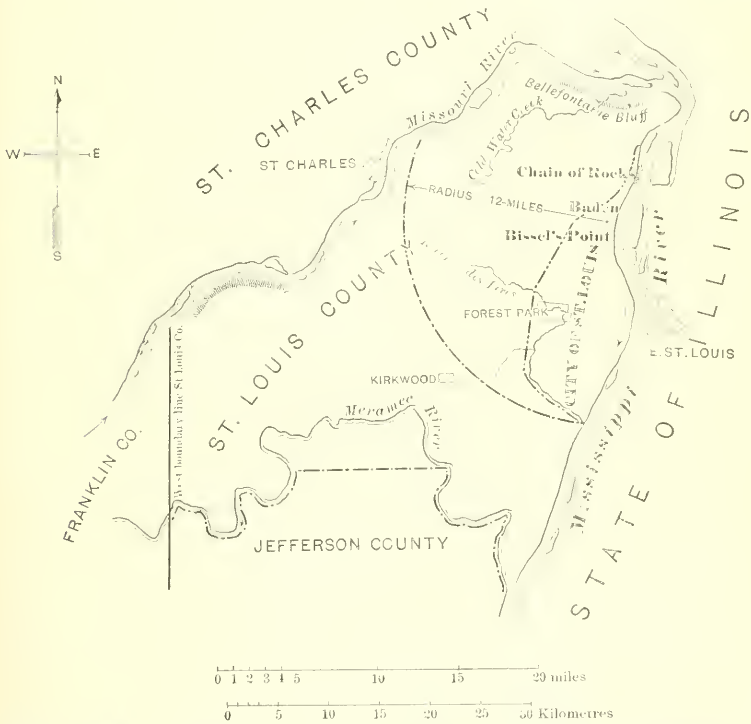
IV. Quality of the Supply.

By Robert E. McMath, Member of the Engineers' Club of St. Louis.

[Read April 18, 1894.]

A few years since, a question as to the quality of Mississippi, and especially Missouri, river water would have been treated with derision, but now even the old time St. Louisian must admit that the foundation of his faith is badly shaken. A vast area is tributary to the Mississippi at the point where our supply is to be taken, and each small district

pays that tribute in a manner characteristic of itself. The result is a composite of waters from many sources. Mingled with the water is the debris of mountain and plain, as matter in suspension or in solution. Of the matters in suspension, whether of vegetable, animal or mineral origin, none adds any desirable quality or character to the water. By common consent it is desirable to be rid of them all. Of matters in solution, some may be neutral, beneficial or harmful for one or more of the uses to which water is put in a great city. A water pure according to scientific standards would suit no one. If chemists, individually connected with the varied interests of water users, were called upon for formulas of the ideal



SKELETON MAP OF ST. LOUIS COUNTY, MO. SCALE, 1 INCH = 12 MILES.

water, a strange diversity would be developed. Nature's mixture, as we have it, probably comes as near the mean of such ideals as is possible, for it contains a little of everything from everywhere. Recently some of our people have awakened to the probability that our water has an undue contribution of something from Chicago, and hence in large part the query which furnishes occasion for this paper.

As to the source of our supply I remark, first, that this must of necessity be the river. Second, that the location at the Chain of Rocks

is plainly designated by nature, for that is the only possible point of supply on the Mississippi, and it is also on the only practicable line by which a supply can be brought from the Missouri.

The first of these propositions needs no argument, except to put aside the occasionally suggested scheme of using Meramec water, by reminding you that the Meramec drains a mineral region and is liable at low stages to be mineralized to an extent unfitting it for use as drinking water. Concerning the scheme to bring in the water of St. James Spring, I will say no more than to suggest that water which has probably traversed a series of bat guano caves is not necessarily pure, even though it be clear.

To establish the second proposition, I call attention to the fact that the Bellefontaine Bluff on the Missouri is the only place, until we approach the limits of St. Louis County, where the river runs along a permanent bank. That bluff can be reached from the Chain of Rocks by a tunnel four and a half miles in length that will deliver Missouri water into the wet well at the Low Service Station.

Since the river has disposed of a site above St. Charles, once considered possible, by leaving that site more than a mile inland, there are but two places where a permanent intake could be maintained, that at Bellefontaine and one near or beyond the west line of St. Louis County, distant by an air line twenty-one miles from the nearest point in the west boundary of the city, at Shrewsbury Park. The same point being, by air line sixteen miles from Bellefontaine Bluff. The conclusion is that the location at the Chain not only serves the wants of the city of to-day, but absolutely commands the water supply of that greater St. Louis which some people can see with the mind's eye.

Much criticism has been expended on those who overruled for a time the recommendations of Mr. Kirkwood that the Chain of Rocks be the location of the Low Service and Baden that of the High Service stations, and who established both at Bissell's Point; but the fact that we find among those whose counsels prevailed, such men as Gerard B. Allen and James B. Eads warns us against too hasty judgment. A glance at the city map will suffice to prove that Bissell's Point is well located as a point of distribution. It is not now a proper location for an intake, and, as a result, the city has on its hands a low-service house and three well-worn engines, and a boiler-house with a battery of antiquated boilers for which it will shortly have no further use; but the settling basins, as filter beds or as a storage reserve, retain their full value, as do also the high-service houses and engines, less wear and tear. The Kirkwood plan was good, as is evidenced by the fact that we are now carrying it out, so far as location is concerned; but it outran the resources and actual needs of the day when it was proposed. The map

shows us the Cold Water or St. Ferdinand Creek emptying into the Missouri near the upper end of Bellefontaine Bluff. This creek drains an area which, even now, is being invaded by the suburban site speculator, and which at no remote date will receive the sewage of a large population. But if we indulge the visions of our prophetic eyes, we are liable to fall into the error of the housewife who, by preparing for an extra good dinner, left breakfast uncooked. We therefore adopt the Chain of Rocks for the location of pumping and settling works, and point to the Bellefontaine Bluff as a possible future intake point.

What shall we say as to the location of the high-service stations?

Let it be understood that we are dealing with the question of a water supply for St. Louis from 1894 to 1920 at farthest.

If arcs of different radii be struck from the Baden location as a center, it will appear that a greater area can be supplied from that point than from any other which can be reached by gravity [illegible]y from the settling basins. The location is on a direct line from the [illegible]ettling basins to the northwest corner of Forest Park. Hence it is an eligible location for the supply of the western part of the city and of the adjoining suburban territory.

The highest ground in the city limits north of the Pacific Railroad is almost centrally divided by the line mentioned. The line to the high elevations south of the Pacific Railroad is also direct and as short as any. The highest elevation within the city limits north of the railroad is about 180, above directrix, at the southwest corner of Forest Park; the highest south of the railroad is 205, at the Female Hospital. The highest graded point in the old city limits (prior to 1876) north of the railroad is 140; south of the railroad, 159.

Taking 30 pounds pressure at street grade as standard, a reasonably satisfactory supply from the present works north of the railroad is limited by the grade contour of 130, while south of the railroad the limit is that of 125 to 120. These facts suggest that the Baden Station should be designed to supply the high levels, and that the Bissell's Point Station be maintained to supply the lower levels.

Should it be deemed necessary to filter the water for domestic use, a third standard of pressure may well be considered. For very many manufacturing establishments filtered water will be no better than settled water. Most of these establishments are now, and for transportation reasons they always will be, located on ground below the grade contour of 75. If, therefore, a plant be operated to deliver settled, but unfiltered, water in this low district, manufacturing interests will be promoted by a less water rate than would be possible if filtered water alone were supplied, and the further problem of finding employment for ground now depreciating in value will be solved. Still farther, if users of large

quantities of water locate on the low lands north of Bissell's Point, it will be entirely practicable to supply them at a still lower rate with settled water direct from the conduit.

To carry out this idea, one of the high-service houses at Bissell's Point would handle water, filtered probably in the present settling basins, and pump 30 million gallons per day against a head of about 220 feet; the other pumping daily 30 million gallons of unfiltered water against a head of about 130 feet. The Baden Station might be divided into two services, the one part pumping against 220 feet head, the other against about 315 feet. Of course, economy demands that, so far as possible, territory which requires the high head should be served separately.

Consideration has been given to the suggestion of a supplementary detached station for the highest service; but the weight of argument seems to be in favor of concentrating all pumping machinery at the main stations.

From this outline of a possible development of the water works, a matter having a close relation to the consideration of quality, I pass to the still more closely related question of purity; meaning, by purity, freedom of the water from any mixture or contamination which would render it dangerous to human health.

From what I have already said you will have gathered that, as we are at present situated, the water supply must be taken from the Mississippi River at the Chain of Rocks, or, as an alternative, from the Missouri River at the Bellefontaine Bluff.

When the Chain of Rocks was adopted as the location whence the supply for the immediate future should be taken, it was virtually assumed that water there taken would be wholly from the Missouri. The well-known phenomenon that an apparent line of demarkation between the waters of the two rivers is noticeable at the city front was triumphantly quoted as demonstration that none but Missouri water could reach the proposed intake. Hence it was urged that to go to the Missouri itself was an unnecessary expense. While coming down the river in October, 1887, I saw what led me to the conclusion that at that time, and probably at all low stages, a mixture of the waters of the two rivers took place immediately at their junction.

What I saw was the water of the Missouri dropping into that of the Mississippi over a fan-shaped reef extending across the mouth of the Missouri; the muddy water of the Missouri, plunging under the clearer water of the Mississippi, came to the surface in irregular boils and patches, some rising near the Illinois shore. Later, I noticed that although the water appeared densely muddy when looked at vertically from the steamer's deck, yet the bow-wave, when first started from the

Fig. 1.—Plan of Conduit.

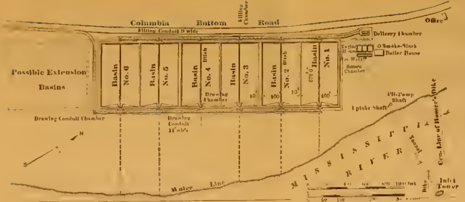


Fig. 4.—Low-Service Extension at Chain of Rocks.

Fig. 2.—Section of Conduit and Embankment.

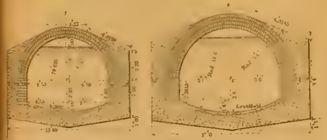


Fig. 3.—Sections of Conduit.

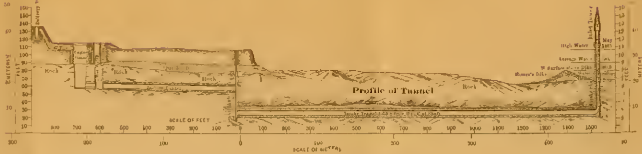


Fig. 5.—Profile and Sections of Tunnel.

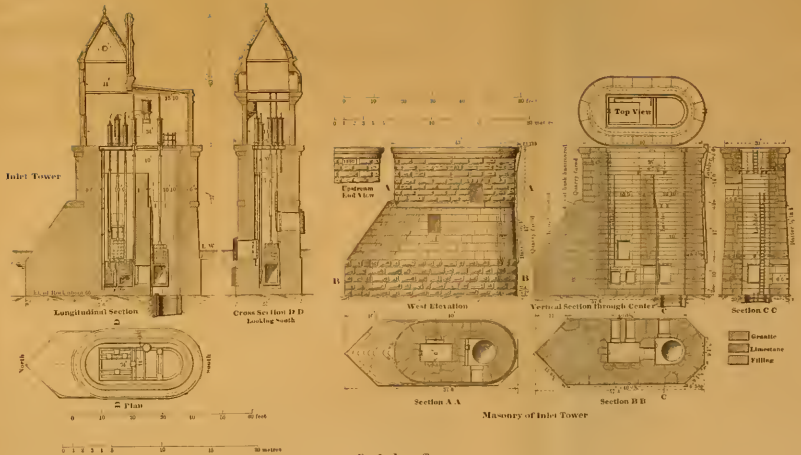


Fig. 6.—Inlet Tower.

stem and broken, showed comparatively clear. I was thus compelled to recognize the fact that Mississippi water tended to overlie that of the Missouri, and hence that it might, and probably did, extend well over to the Missouri shore, and that consequently some proportion of Mississippi water would be taken into a supply drawn at the Chain of Rocks.

Reporting what I had seen to Mayor Francis and my associates on the Board of Public Improvements, and thus raising a question as to the sufficiency of the traditional belief, I also suggested the advisability of making an investigation, chemical and biological, of the water of the Illinois River, in order to determine, if possible, whether any risk to the health of St. Louis would be incurred by taking our water supply at a point where it is well nigh certain that water which has passed through the sewage pumps at Bridgeport will in some proportion enter that supply.

Being at the time a believer in the doctrine that dilution and opportunity for oxidation would certainly render sewage harmless, my expectation was that such an examination would bring out strong evidence that the supply might be taken there without risk of harm. Later evidence has shaken my faith in the doctrine, but has not proven the contrary.

As a consequence of my report, the Water Commissioner, taking due precautions to guard against misleading results, obtained samples of water from the Mississippi above the influence of the Missouri, from a corresponding point in the Missouri, and at the Chain of Rocks, and obtained a chemical analysis of them by Prof. W. B. Potter, Manager of the St. Louis Sampling and Testing Works. The details are fully set forth in the report of the Water Commissioner for the fiscal year ending April, 1888, pages 71, 72 of the Report of the Board of Public Improvements.

These results confirm the observations I have described, and prove that, although the characteristics of Missouri water greatly predominate at the Chain of Rocks, the influence of the Mississippi water is clearly manifest. The increase of the mixture of the waters with the distance traversed is shown by the results at Bissell's Point. It must therefore be taken as an established fact that at low stages, or during the fall and winter months, the water which has been furnished our city from Bissell's Point has contained a considerable proportion of Mississippi River water, and probably some of it from the Illinois and the Bridgeport pumps; also that the supply taken at the Chain of Rocks will contain a diminished proportion of water from the same sources

Since the foregoing evidence was obtained, the city of St. Louis has been visited by a serious outbreak of typhoid fever, lasting through the fall and winter months of 1892 and into 1893. Our Board of Health,

by its official action, laid the outbreak to the charge of a contaminated water supply, and so gave publicity and official sanction to a report injurious to our city.

The progress of this outbreak, as per official report, was:

	Deaths.	Cases.
January, 1892,	13	22
February, "	8	22
March, "	7	18
April, "	9	14
May, "	8	13
June, "	6	32
July, "	15	35
August, "	8	70
September, "	23	142
October, "	45	261
November, "	111	1923
December, "	189	945
January, 1893,	36	114
February, "	17	35
March, "	8	40
April, "	8	
May, "	3	
June, "	2	
July, "	11	
August, "	42	
September, "	32	
October, "	20	
November, "	25	
December, "	11	
January, 1894,	2	
February, "	7	
March, "	8	

The summer of 1892 was a flood season in the Mississippi, and the bottom lands north of Grand Avenue were submerged for many days. The sewer outlets along the entire city front were blocked by backwater for months. Yet it is reported that the 1st, 2d, 3d, 4th, 5th, 6th, 8th, and 13th wards, where these influences were most potent, furnished comparatively few cases. The disease was chiefly prevalent between Twelfth Street and Vandeventer Avenue, Victor Street on the south and Herbert Street on the north; or, by house numbers, between 1200 and 3900 east and west, 2500 south and 3500 north.

It is not apparent why a charge was brought against the water supply, which had certainly the same character throughout the city when some of the most densely populated wards were nearly exempt. It will also be observed that the disease was present to a sufficient extent to have put the health authorities on their mettle during the early

months. The decided spread began in June, reached its maximum in cases in November, and quickly fell. The cause can hardly be found in the water supplied, for the increase began when the river was approaching a flood stage, when certainly the probability of contamination by sewage from other cities must have been infinitesimal. As the river approached a low stage, and the probabilities of sewage contamination increased, the disease abated; and when the rigors of a severe winter covered the streams with ice, and so brought the sewage of Chicago and other up-river cities to our doors under conditions as unfavorable to self-purification as can well be imagined, the disease fell to its normal I think that the water supply is entitled to a verdict of acquittal, having shown an alibi. A further cry was made, and the city was nigh being dragooned into a large expenditure to hasten the transfer of the intake to the Chain—by temporary expedients that would have seriously interfered with the permanent works. But that the flow from Harlem and other suburban creeks had nothing to do with the typhoid scare is well evidenced by the fact that very few cases of the fever occurred within their drainage areas.

I conclude that as yet no evidence has appeared to justify an unfavorable opinion as to the quality of our water supply. Further, the analyses of 1887, already referred to, indicate that, contrary to traditional ideas, the Mississippi water is not only clearer than that of the Missouri, but has materially less sulphuric acid, lime, magnesia, chlorine, iron and alumina, and is lower in hardness. Therefore, so far as chemistry is concerned, it is the preferable water.

The quality of our water, so far as appearance and usefulness are concerned, is open to improvement. The mud, and sometimes the coloring matter, are unbearable. In days not very remote, the St. Louisian who did not argue that the mud was a positive advantage, was the exceptional character. The one who does so argue is now the exception. Still, I think that all of us, when in other cities, particularly in those which take their supplies from the great lakes, find something lacking, and we long for a satisfying draught of Mississippi water. I am not disposed to attempt telling you affirmatively what the lack is; but negatively I will say it is not the absence of mud. Experience and experiment has taught our water-works men that settlement for twenty-four hours in a reasonably quiet basin will clear the water of nearly all of its sediment. A cloudiness will remain after a long period of rest. Apparently, the interest of purity rather favors the adoption of a twenty-four-hour period for settlement. It is also to be noted that at the breaking up of winter there is usually a time when a persistent dark color, a disagreeable black deposit and an unpleasant flavor prevail; and these are not removed by settlement. In summer flood time the mud is at its maximum; but the

water, when settled, is free from unpleasant flavor, although it retains a stain.

What may we expect when the new works are in operation? So far as freedom from mud is concerned, I know of no reason to look for better results than were realized when the Bissell Point works were first completed, results which continued until the capacity of the settling basins became overtaxed.

Our spring and summer supply never gave us clear water, and probably never will. I anticipate that the advancing tastes and habits of our people will demand something better than can be attained by settling alone. Whether that something will require filtration, or may be practically attained by some process of clarification, is an unsolved question of great importance. The success of many filters depends largely upon the use of some coagulant, of which alum may be named as a representative, because most frequently used. If just the right proportion of alum is used, no trace of it can be found in the effluent, and, of course, no harm can follow. If a coagulant is to be used to assist filtering, is it not better to use it at the low-service works, and for all the water pumped, than at filter stations near the high-service pumps, further inland, for perhaps a part?

That a substantial gain, as to quality, would follow a more complete clarification, is indicated by the average results of a series of analyses of samples taken from mid-channel, from the distributing well and from the clear well.

The average results from 16 groups taken at stages of water ranging from 67.6 to 100.2 (directrix = 100), and in season from mid-winter to mid-summer, show:

	Parts in 1,000,000. Channel.	Dist. Well.	Clear Well.
Alb. Ammonia	1.046	1.033	0.411
Free Ammonia	0.038	0.046	0.019
Nitrites	0.0002	0.0003	0.00018
Nitrates	0.383	0.381	0.442
Oxygen consumed	31.60	33.00	15.90

Or, assembling series of similar dates, in order to show the gain by sedimentation:

Date of Collecting.	Gauge of River.	Temp. of Water.	Oxygen Consumed. Parts per 1,000,000 by Weight. Channel.	Dist. Well.	Clear Well.
June 27, 1893	89.9	27° C.	41.40	47.80	17.80
July 8, 1893	89.5	27° C.	46.80	44.60	15.40
July 12, 1893	85.0	27° C.	45.80	48.60	20.80
July 19, 1893	81.0	28° C.	43.40	41.00	18.20
July 26, 1893	79.6	28° C.	38.40	38.40	15.20
August 31, 1893	72.0	22° C.	21.40	25.80	17.10
November 5, 1893	70.4	10° C.	7.80	5.80	5.20
December 6, 1893	67.6	1° C.	7.00	7.00	5.60

If the sedimentation, occurring during the passage of the waters through our present settling basins, reduced the carbonaceous matter by an average of 60 per cent. when the river was 20 feet or more above low water, then, with the better settling facilities, afforded by the new works, we may confidently expect a much higher percentage of purification.

A comparison of determinations of albuminoid ammonia would sustain this conclusion, but purification in this respect will not necessarily be accompanied by a corresponding improvement in appearance.

If to natural settling we add the clarification due to use of a coagulant, we may well expect a water as free from objectionable matter, organic and inorganic, as is practicable; still, not a water to satisfy the fastidious, for at times it will have a dark shade, and at all others more or less of a whitish cloudiness.

To meet the last requirement, filtering must be resorted to. But, it may be asked, should the city be compelled to filter the entire supply in order to meet a demand arising from only a part of its people? Probably less than half the water supplied would be improved for the use to which it is put by this last and costly process. Considering the fact that filtered water rapidly deteriorates, would it not be better to leave the filtering to those who want it?

These are questions any one may ask, but who has the answer ready?

As yet, I have not touched upon the question that perhaps, in your minds, is most vital to the quality of our water, viz.: How will it be affected by the completion of the Chicago drainage scheme?

Let us assume the worst conceivable condition: the Missouri and Mississippi dead low; their joint volume about 45,00C cubic feet per second, and the Illinois frozen from its mouth up, so that whatever may under present conditions enter the Chicago canal, will be delivered at the mouth of the Illinois as if it had come through a closed pipe. Then, as was the case in 1892–3, nearly 2 per cent. of the water passing St. Louis will have passed through the Bridgeport pumps. When the drainage canal is in operation, with a flow of 10,000 cubic feet per second, the proportion of water that has been subject to Chicago influence will be 18 per cent., a prospect which, of itself, is not reassuring. Let us look closer.

Estimating the sewage proper as equal to the water supply, we may roughly estimate that of the delivery of the Bridgeport pumps 20 per cent. is sewage and that the remaining 80 per cent., while originally lake water, has been in very bad company during its leisurely trip through the Chicago River. Under the proposed condition of 10,000 cubic feet flow per second, the sewage proportion will fall to about 4 per cent., and the 96 per cent. will have passed through Chicago without stopping.

Using these proportions, it seems that $\frac{3}{10}$ of one per cent. of the present low stage Mississippi flow has been in the condition of sewage, and that this proportion will rise to $\frac{7}{10}$ of one per cent , when the $2\frac{1}{2}$ million mark of Chicago population within the sanitary district shall have been reached. Hence, unless we are helped by mere dilution from the beginning, the quality of Mississippi water will, as a whole, have suffered from the Chicago scheme.

But these and similar arguments prove nothing in reality, although the figures represent facts.

The underlying question is: Does water, which washes nearly everything else, wash itself? In other words, does it, by any process, rid itself of filth after contamination? We know that it does: by sedimentation and by chemical change, in which lower forms of organic life may have an important part.

But how are we to know, when the chemist assures us that all the ammonia that left Chicago has passed into harmless nitrates before reaching St. Louis, that some colony of pathogenic bacilli has not made the voyage with unimpaired vitality? I have no answer to this question. When we think of all the risks and dangers we are said to incur with every breath we inhale, every morsel we eat and every draught we drink, we may well wonder that our harp of a thousand strings keeps in tune so long. While ignorant of these risks, the race lived and it probably will continue to live in spite of what biologists tell us.

Scientists are to be commended for their patient and painstaking researches, for seeking to penetrate the mysteries which surround us; and if, under strong temptation, they sometimes tell us things before they know them themselves, as possibly some have done in the matter of St. Louis water, we engineers need not throw stones at them, for we have glass sections in our own house.

Much has been said locally about the scheme by which Chicago aims to cast her filth before us. It may be wrong for her to do so, but St. Louis cannot of herself collect the proof; partly because she cannot find the men and the means for the demonstration, and partly because any action in this direction will be attributed to jealousy, and any proof furnished will be much discredited on account of traditional rivalry.

The questions involved are of the utmost importance, not only to the cities immediately interested, but to all the cities and states on the earth. It is, therefore, proper that the United States Government be asked to make a full investigation of the facts presented by the Illinois River, and of the effect of Chicago sewage on it, especially when the river is frozen.

A disinterested examination would lead to wise legislation, regulating, controlling or prohibiting the discharge of sewage into streams and

rivers, small and great, by Minneapolis, St. Paul, Omaha, Kansas City, St. Louis and smaller cities.

As the population of this country becomes more dense, the question of the quality of water supply will become more important, and our efforts may of necessity turn from the prevention to the cure of pollution.

To completely guard the purity of our streams is not possible, and hence the purification of water will probably become a necessity; but that probability should not lead to indifference as to the pollution of the streams.

Returning for a final glance at the Chicago plans, I will say that already a very large part of Chicago's territorial area, and a considerable part of her present population, are outside of the sanitary district to be served by the canal. Moreover, the canal is only an outlet for Chicago drainage, and it must be remembered that drainage is a matter entirely distinct from the disposal or treatment of sewage. Chicago's sewer system will have to be radically remodeled to complement the drainage plans. Perforce she will have to separate sewage from storm water, and will have to pump a large part of the sewage. Under this necessity, imposed by natural conditions, it will be comparatively easy for the State of Illinois, or, in default of her action, for the general government to impose a further condition that the sewage be purified before delivery into the waters of a navigable stream.

When I promised the Secretary of the Club to undertake one of a series of papers on the new water works, I did not appreciate the poverty of the information available to me concerning quality of supply. Certainly, there is much that might, and should, be known concerning Mississippi or Missouri water, the variations of quality with season and stage, and other matters of inquiry.

No systematic study of our water had been made prior to 1893, and then only by chemical analysis. In preparing this paper, I have had in my hands the report of Chemist John T. Wixford to Water Commissioner M. L. Holman, with liberty to use it; but, with the exception of a few figures showing grouped results and a general statement of conclusions, I have made no use of the information it contains, chiefly because I am persuaded of the truth of the statement somewhat fully presented in the report by Mr. Wixford, that the usual lines of inquiry in examinations of water supply are of little or no value when applied to Mississippi water. Such studies usually take note of color, odor, taste, turbidity, solids in suspension (and their composition). They involve the determination of dissolved gases, and special determination of chlorine, organic carbon and nitrogen, ammonia salts, nitrites and nitrates, and also take account of hardness.

The color of unfiltered Mississippi water varies from muddy-brown to whitish, according to the character of the suspended matter. Filtered, the color is a faint yellowish-green. The odor is inappreciable, and the taste is agreeable, except for a short period at the breaking up of winter, at which time the color is dark and persistent. The origin of this color and taste is not known ; but it is not probable that a remedy or preventive lies within human power. The turbidity is always considerably greater at high stages than at low, and when the river is rising than when it is falling. The causes are uncontrollable. The solids in suspension are, both in quantity and in variation, far beyond the possibility of discovering the influence of sewage contamination, and their determination would have no value.

The dissolved gases are constituents of the atmosphere, and are harmless. They thus indicate no recent sewage contamination. It is needful, first, to know the normal quantities, as it is only the excess that is to be taken into account. This, for varying conditions and temperatures, is not practicable.

The chlorine test is valueless, because we do not, and cannot, know the normal scale. The Massachusetts State Board of Health has published a map showing the iso-chlors for that State, which vary from 0.65 part of chlorine per 100,000 near the coast to less than 0.10 part in the western part of the State. If an iso-chloric map of the Mississippi and Missouri basins were made, the maximum would probably surround the Kansas salt fields; but as we never could tell what proportion of the flow at any time came from a particular part of the drainage area, we could make no use of the map.

Organic matter, animal or vegetable, is mainly composed of carbon, hydrogen, nitrogen and oxygen in varying proportions. Animal matter decomposes more rapidly than vegetable matter, and contains more nitrogen. By decomposition, these elements are converted into carbonic acid, water and nitrates. The changes are the result of the activity of micro-organisms, and do not take place in their absence.

Albuminoid ammonia represents the nitrogen in organic matter which has not begun to decompose. In itself, it does not indicate whether it comes from animal or vegetable matter. By one determination, July 12, 1893, there was present 1.799 part in 1,000,000.

Analyses by the Massachusetts Board of Health give 5.302 parts in 1,000,000 as the average yield of Lawrence sewage. Hence, Mississippi water at mid-summer stage may have one-third as much albuminoid ammonia as average sewage. It is not necessary to follow out Mr. Wixford's computation to show that it would take the sewage of 454 cities like St. Louis to account for this proportion of albuminoid ammonia.

Hence, to look for trace or proof of sewage contamination by analysis, is as hopeless as the search for a needle in a haystack.

Not to follow the technical report further, it is suggested that a study of our water supply involves the development of a broader field of investigation than has yet been traversed, and one which can scarcely be covered by the limited resources of our water department.

V. The Filtration of City Water Supplies in the Light of Recent Researches.

By Robert Moore, Member of the Engineers' Club of St. Louis.

[Read May 2, 1894.]

One of the most important and difficult problems with which the modern city is confronted is how to obtain an adequate supply of wholesome drinking water.

The first solution in point of time is, in the great majority of cases, found in surface wells, one of which is sunk for the supply of each house or small group of houses. For a time this source of supply is satisfactory both as to quantity and quality, and it may be that for many years no water works beyond the town pump are demanded by any public or private need. With the lapse of time and the growth of population, however, the water obtained from surface wells is found to deteriorate in quality. The cesspools after a time pollute the wells and under favoring conditions convert them into breeders of disease. The favorite home of typhoid fever, the world over, is the country village. But as a rule other considerations of less intrinsic importance have a greater influence in producing a desire for something better. The private citizen wants to have water brought into his dwelling, and an ample supply of water under pressure becomes necessary as a protection against fire.

The next step, therefore, is to bring the water of the nearest lake or river into the town, and the private well is supplanted by the public water pipe. This step is attended not only with an enormous gain in security from fire and in comfort of living, but also, in nearly all cases, with a marked improvement in the public health. Statistics compiled by the Massachusetts State Board of Health * show that in the twenty years from 1865 to 1885, during which all the larger towns had introduced public water supplies, the deaths from typhoid fever had fallen from a rate of 13.04 to 3.09 per 10,000, a decrease of 70 per cent.

This reduction of the death-rate, however, is not universal, and

* Twenty-second Annual Report, p. XXII.

even in the same city is not always constant. In a few cities having a public water supply we find the typhoid death-rate to be increasing rather than decreasing. Three well-marked instances of this kind are cited by the Massachusetts State Board of Health,* to wit: Holyoke, Lowell and Lawrence; and a notable instance of the same kind is found in our neighboring city, Chicago. In each of these cities careful investigation has shown the water supply to be unmistakably polluted by causes which can be positively identified. In the case of Chicago the rise in the typhoid fever rate has been shown by Dr. F. W. Reilly, Secretary of the Illinois State Board of Health, to follow the freshets whereby the waters of the open sewer known as the Chicago River have been carried into the lake and thence into the city water pipes; whilst periods of long-continued dry weather, during which the Bridgeport pumps are able to reverse the natural flow of the river, are followed by corresponding depressions in the fever curve.

These cases, however, are only illustrations of what is likely to happen hereafter to many other cities. The increasing density of population in the territory draining into our lakes and rivers is certain to cause pollution, and in the cities dependent upon them as sources of water supply, the public water pipes are sure in time to become carriers of disease. How to ward off this new danger is a problem which has for a long time troubled many cities in the old world and which is beginning now to trouble not a few cities in the new world.

The first and most natural suggestion by way of remedy is to change the source of supply, substituting a new one that shall be free from danger. This was done by Glasgow, which, prior to 1859, took its water from the Clyde, but which since then has taken it from Loch Katrine, thirty-four miles distant in the Highlands. As a result, the city has shown itself, in every epidemic of cholera since then, to be cholera proof, although it had always before been one of the most vulnerable. This is also being now done by the city of Manchester, which is building works to take its water from Thirlmere, more than eighty miles distant in the Lake District.

Such a change of sources evidently affords a complete solution of the problem, and not a few have maintained that it is the only solution. For example, Mr. Chas. Watson Folkard, Associate of the Royal School of Mines of England, in a paper read January, 1882, before the Institution of Civil Engineers, after a discussion of the various methods of water analysis, uses this language: †

"The conclusion that once-contaminated water never purifies itself sufficiently for dietetic purposes becomes inevitable; and, as chemical

* Twenty-second Annual Report, for 1890, p. 525 and following.

† Proceedings, Institution of Civil Engineers, Vol. 68, p. 66.

analysis fails to give reliable evidence as to its fitness or the reverse, the author believes that the only safe test of the wholesomeness of a given water is by tracing it to its source and ascertaining that no objectionable impurities gain access to it. This will at once condemn all rivers flowing through a populous country; and, if it be considered that a river is the natural drain of a district into which everything soluble or suspensible finds its way, it will not be a matter of wonder that this should be the case. No Conservancy Board can keep pollution out of a river; it must receive all the rain falling within its watershed (excepting, of course, that which is evaporated) together with the overflowings of cesspools and the sewage of towns within the same area. It is part of the great circulatory system of the earth, which it is vain for man to attempt to control. This being so, it is evident that rivers, except near their source, can only afford polluted water, and a problem utterly insoluble by man is presented, viz., the purification of foul water on a large scale."

In the discussion which followed, in which a number of very able men, including Prof. John Tyndall, took part, the preponderance of opinion was in full agreement with the author. That drinking water for individuals and for communities should be taken only from sources that were not "contaminated nor contaminable" was the judgment of nearly all.

But, unfortunately, for the great majority of towns such sources as these are inaccessible. For most of them there is practically no choice. St. Louis, for example, unless she would do worse, must draw her water-supply from the Mississippi or the Missouri; Louisville and Cincinnati, from the Ohio; and Chicago, from Lake Michigan. Each must take what there is at hand and make the best of it. The real problem, then, for many cities now, and for nearly all cities at sometime hereafter, is how to render wholesome a water supply that has been contaminated.

The earliest device for obtaining a pure supply from a river whose water is for any reason objectionable, is to take the water, not from the river directly, but from wells sunk in the sand near by. By this method, which is sometimes called "natural filtration," a water free from sediment or visible impurity, is obtained, and if the quantity required be not large the result may be entirely satisfactory. In the greater number of cases, however, this method is not attended with success. Most often there is a deficiency in quantity, and not infrequently the quality also is at fault. As is well known, the water obtained from wells alongside the Mississippi River near St. Louis is much harder than the river water, and is usually unfit for use in steam boilers. At the water works near Lake Tegel, one of the works for the supply of Berlin, the water was at first taken from wells alongside the lake. But experience showed it to be so rich in iron and so favorable to the development of objectionable vegetable growths

that the water was rendered useless. The wells were therefore abandoned and the water is now taken directly from the lake.

The next device in the order of time was the artificial sand filter, first constructed by Mr. Jas. Simpson, Engineer, for the Chelsea water works of London in 1839. This consists essentially of a shallow reservoir with a collecting drain through the center and with lateral drains of porous tiles or bricks, without mortar, leading into the central drain. On top of this system of drains are laid from three to four feet of gravel and sand increasing in fineness to the top. Through this sand bed the water is allowed to percolate slowly into the collecting drains, whence it is led off to the pumps for distribution.

This simple device was from the first so effective in removing sediment and improving the appearance of the water that in 1852 its use was by law made obligatory upon all the London water companies except for water from deep or artesian wells, and it has ever since been in continuous and successful operation. The example of London was soon followed by other cities, both in England and on the Continent, so that when Mr. Kirkwood visited Europe in 1866 on behalf of the Board of Water Commissioners of the City of St. Louis, he found filtration plants in operation in Berlin, Altona, Nantes, and Marseilles, as well as in Leicester, York, Liverpool, Edinburgh and Dublin.

So long as the pollution of water was regarded as due solely to particles of dead organic or inorganic matter in suspension, this method of purification left nothing to be desired. By its use, turbid waters were rendered clear and, so far as the eye could judge, pure. But when, in the progress of scientific investigation, it became evident that the harm of polluted water lay, not in dead matter at all, but in living organisms invisible to the naked eye, and that the clearest and most sparkling water was sometimes the most deadly, a strong revulsion of opinion took place, and the benefits of filtration came to be generally regarded as delusive. This sentiment is well voiced in the paper of Mr. Folkard and the discussion thereon, already referred to.

"Filtration," says he, "is another remedy put forward as infallible by those who have not grasped the subject. How can filtration affect substances dissolved in water? And, as far as the minute organisms found in putrescent bodies are concerned, they could pass a hundred or a thousand abreast through the interstitial spaces of ordinary sand as used for this purpose." *

And Mr. Homersham declares that in some respects and at some seasons filtration really injures the water by the collection of a layer of

* Proceedings, Institution of Civil Engineers, Vol. 68, p. 68.

organic matter on top of the sand which furnishes "pabulum for the insects" as he terms them.*

This, added to the difficulty of finding and recognizing the morbific germs—a difficulty so great that, as Dr. Tidy expressed it, "one could no more analyze a water for a germ of typhoid than one could analyze a brain for an idea"—left the matter in a quite hopeless condition which seemed to justify the opinion of Mr. Folkard already quoted, that the purification of foul water on a large scale was "a problem utterly insoluble by man" and that there was no defense against impure water except boiling or distillation. This, however, is a defense which is almost impossible of application on a large scale and, as those who have tried it in their own households know, very difficult of application even on a small scale.

Now, as it happened, in the very year in which this paper was read, 1882, Dr. Robert Koch of Berlin gave to the public† his then newly discovered gelatine-plate process, which made it possible to fix, cultivate and even count the micro-organisms in any sample of water. This at once put the biological analysis of water, which Dr. Tidy had just declared to be an impossibility, upon the footing of an exact science, and students were not wanting to apply the new method to the investigation of the phenomena of the filtration of water through sand.

Among the earliest in this new field of inquiry was Percy Faraday Frankland, Professor of Chemistry in University College, Dundee, and son of Dr. Edward Frankland, official water analyst for the Registrar General and for the Local Government Board of England. Prof. Frankland began at once to study, by the aid of the gelatine-plate process, the various methods of water purification, and in particular to ascertain, by a series of observations running through several years, the results actually attained by the filters of the London water companies. The facts thus found are set forth in a paper read by him before the Institution of Civil Engineers in April, 1886, and in two papers submitted to the Royal Commission on Metropolitan Water Supply and published with other documents accompanying their report of September 8, 1893. In brief, his findings are these:

(1) That the chemical changes effected in the water by the filters of the London companies, summarized in the following table, are so small as to be quite insignificant.

* Proceedings, Institution of Civil Engineers, Vol. 68, p. 70.

† Mittheilungen, Kaiserliches Gesundheitsamt, 1882.

TABLE SHOWING THE CHEMICAL RESULTS OF THE FILTRATION OF THAMES WATER BY THE LONDON WATER COMPANIES, EXPRESSED IN PARTS PER 100,000.

		Before Filtration.	After Filtration.
Total solid matter		28.40	26.20
Organic carbon		.123	.119
Organic nitrogen		.025	.022
Ammonia		0	0
Nitrogen as nitrates and nitrites		.077	.089
Total combined nitrogen		.102	.111
Chlorine		1.6	1.6
Hardness	Temporary	11.5	10.9
	Permanent	7.1	7.1
	Total	18.6	18.0

(2) That the filters have a most remarkable efficiency in removing micro-organisms from the water. The record of three years' working of the filters is given in the following table, which shows that on an average, out of every 100 micro-organisms in the untreated river water, the numbers stated in the table were removed by the water companies before distribution.

Water from the	1886	1887	1888
	Organisms.	Organisms.	Organisms.
Thames	97.6	96.7	98.4
Lea—East London Co.	96.5	95.3	95.3

From a later series of observations made in 1892, Prof. Frankland finds the average number of bacteria per cubic centimeter in the filtered waters to be only 29, or a trifle more than ⅛ of one per cent. of the average number in the Thames water—20,000. And, as the numbers in the filtered water seem to bear no relation to those in the unfiltered water from day to day, he considers it certain that of those found in the filtered water nearly all are attributable to post-filtration sources. In other words, the efficiency of the filters in the removal of bacteria is practically 100 per cent.

(3) That this extraordinary biological efficiency of the filters depends upon the formation of a superficial gelatinous deposit or membrane upon the top of the sand, which membrane acts as an almost impervious obstacle to the passage of micro-organisms, and that it is of the greatest importance that this membranous film should not be ruptured by the application of excessive or irregular pressures in the filtration.

It thus appears that Mr. Folkard's army of microbes marching "a hundred or a thousand abreast through the interstitial spaces" has somehow been put to rout, and that the cause of their discomfiture is found in the superficial layer of organic matter which, according to Mr. Homersham, should furnish them with pabulum—all of which illustrates anew the extreme danger of *a priori* reasoning in matters of physical science.

FIG. 1. NUMBERS OF BACTERIA IN FILTERED AND IN UNFILTERED WATER AT ZURICH, SWITZERLAND, 1887—1890.

In each of the four diagrams the upper and lower curves show respectively the conditions obtaining before and after filtration.

Other observations of the same character, running in each case through a series of years and all pointing to precisely the same conclusions, have been made by the Massachusetts State Board of Health at Lawrence upon a number of experimental filters, and by the authorities of Berlin and Zurich upon the filters used for the city water supply.

The Lawrence experiments show that when filtering at a rate of from two to three million gallons per acre per day, which gives a velocity of 6 to 9 feet in twenty-four hours, 99½ per cent. of the bacteria in the applied water can be removed by filtration. At slower rates practically all can be removed. At Zurich, where the ordinary velocity of filtration is 25 feet in twenty-four hours, or more than double the London rate, the average number of bacteria per cubic centimeter in the water after filtration is 20. As, however, the number in the water before filtration is unusually low—about 200—the percentage of removal is only 90, or much less than in either of the other cases.

Fig. 1, showing the results of the working of these filters during four years from 1887 to 1890 inclusive, is interesting as showing the tendency of the number of micro-organisms in the filtered water to remain constant without regard to the fluctuations in the number in the water before filtration, a fact already noted in the London and in the Lawrence experiments, and strongly suggestive of the conclusion that the bacteria in the effluent are due to the drains of the filter itself and not to the applied water.

But the benefits of filtration are seen more clearly in the mortuary records than in the records of the laboratory. At Zurich, for example, the typhoid mortality in 1880, before the construction of the present filters, was 4 per 1,000 of the population. Since then it has dropped to 0.4 per 1,000, a decrease of 90 per cent. The effects of filtration in London are shown in Fig. 2, taken from a paper read before the American Statistical Association in January, 1892, by Prof. Sedgwick and Mr. Allen Hazen, which shows the typhoid mortality in London since 1870 as compared with that of several American cities. It is reproduced here with the addition of the typhoid curve for St. Louis since 1867. From this it will be seen that notwithstanding the fact that London draws its water supply from two small rivers draining a territory densely populated, it has had for more than twenty years a typhoid rate continuously lower than that of any large American city.

Even more significant is the report of Dr. William Farr, Registrar General, upon the experience of London with cholera in 1866*, in which he points out that the field of greatest fatality was almost coincident in its boundaries with a section of East

* See Report of Registrar General, July 25, 1868, pp. xv and following.

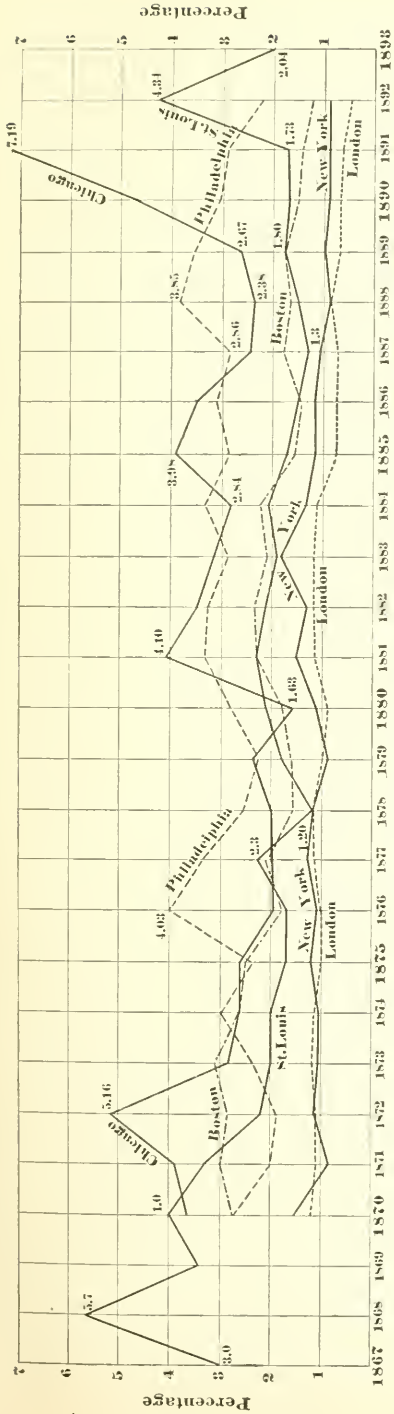


FIG. 2. EFFECTS OF TYPHOID FEVER (IN PERCENTAGE OF TOTAL NUMBER OF DEATHS) IN CHICAGO, PHILADELPHIA, ST. LOUIS, BOSTON, NEW YORK AND LONDON, FROM 1867 to 1893.

London, which, for a time just then, was supplied with unfiltered water—a fact to which he attributes the deaths of nearly 4,000 persons. Of like purport is the now familiar story of Hamburg,* which upon the advent of cholera in 1892,and in spite of the warning given a few years before, by an epidemic of typhoid, was found still drinking the unfiltered water of the Elbe. As a result, nearly 8,000 persons lost their lives from cholera in eight weeks, whereas the adjoining city of Altona, which drank from the same stream after it had received the sewage of Hamburg, but not until the water had been filtered, was, except for certain imported cases, almost wholly exempt from it.

Indeed, no fact in sanitary science is now more firmly established than that properly conducted sand filtration is an almost perfect defense against the dangers of polluted water.

Of the immense and ever growing importance of this fact to all cities dependent upon rivers for their water supply, not a word need be said. But certainly the name of James Simpson, the Engineer who, building "better than he knew," constructed, more than fifty years ago, the first filtration plant, and whose

* Proceedings, Institution of Civil Engineers, Vol. 88, p. 507 and Vol. 114, p. 425.

work has already saved so many thousands of lives, should be held in grateful remembrance as that of one of the benefactors of mankind.

The bearing of all this upon our own city is self-evident; but a few words, by way of reminder of some of the special features of our own case, will perhaps be pardoned. As is well known, in the plans for new water works for St. Louis, made in 1865 by Mr. James P. Kirkwood, was included a recommendation of filtration. In 1866 Mr. Kirkwood went to Europe on behalf of the Board of Water Commissioners, to make a detailed study of the subject; and, in his report, a copy of which is in the library of the Club, is found a plan for filtration works at St. Louis. Almost the sole object in view at that time was the clarification of the water by the removal of the sediment which was then, as it is now, a cause of reproach to us by the outside world and a source of serious offense even to the citizens native born. With the lapse of time, during

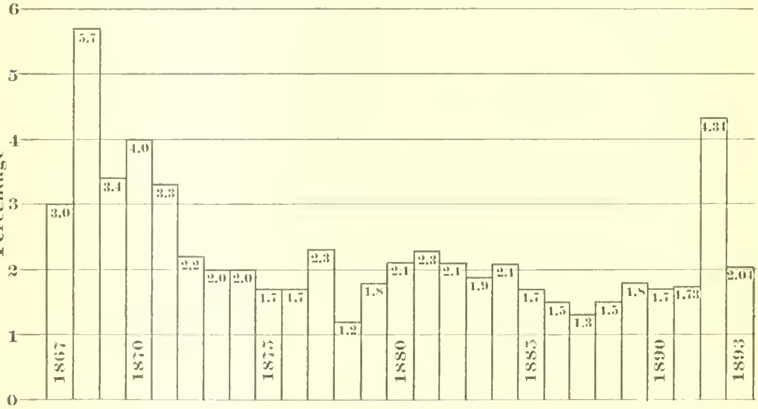


Fig. 3. Effect of Typhoid Fever (in Percentage of Total Number of Deaths) in St. Louis, from 1867 to 1893.

which we have made so much progress in other directions, this reason for filtration has certainly not lost anything of its force.

But a more cogent reason is found in the diagram of relative mortality given in Fig. 2, on which the typhoid rate for St. Louis from 1870 to 1892 inclusive ($2\frac{1}{2}$ per cent. of the total mortality) is seen to be more than double that of London ($\frac{9}{10}$ of one per cent.) for the same period. To make more evident the special characteristics of the St. Louis curve it is shown separately in Fig. 3. On this you will note especially the very high rate from 1867 to 1871, the drop in 1872 and the continuously lower rate from that year on until 1891, the sharp rise in 1892 to $4\frac{34}{100}$ per cent., and the equally marked decline to 2 per cent. in 1893. Worthy of consideration also are the coincident facts that 1872 was the first year

after the removal of the water works intake from the foot of Bates Street, where the water was mingled with the sewage of Rocky Branch and Gingrass Creek, to Bissell's Point, where the water was then comparatively pure, and that in 1893 the pumps, whereby the sewage of Harlem Creek is now discharged into the river below the water works, were first put into operation—facts which in both cases suggest a possible, not to say probable, relation of cause and effect.

But be this as it may, it is certain that our water supply is at times subject to serious infection, which, as time passes, is sure to be largely increased, and equally certain that by means of proper filtration works, coupled with the closing of all wells, our typhoid rate can be reduced to or below that of London. With our present population this means the saving of 1,300 cases and 160 lives each year. And all this can be brought about at a first cost not exceeding two millions of dollars and an annual cost, including interest, of not more than one hundred and fifty thousand dollars—sums which are trifling when compared with the benefits which their expenditure will insure.

TESTS OF NON-CONDUCTING PIPE-COVERINGS.

By John A. Laird, Member of the Engineers' Club of St. Louis.

[Read October 3, 1894.*]

This paper is a report of tests made at the St. Louis Water Works for the purpose of selecting the most suitable covering for pipes, boiler-shells, etc., in the new pumping station at the Chain of Rocks. The specifications for the engine and boiler work called for a covering satisfactory to the Water Commissioner. Not having any data at hand which seemed to be perfectly satisfactory, we concluded to give the different coverings a comparative test under conditions as nearly uniform as possible. For this purpose there were purchased asbestos sponge moulded sectional covering, asbestos fire felt sectional covering and magnesia sectional covering, all for 1-inch pipe. Also, asbestos sponge cement felting, asbestos cement felting, plastic magnesia and fossil meal. Tests were also made on plaster of Paris and sawdust, moulded into covering for 1-inch pipe.

The different coverings were subjected to chemical examination by Mr. Wixford, chemist of the water works, with the following results:

Asbestos Sponge, Moulded.	
Plaster of Paris	95.8
Fibrous asbestos	4.2
Asbestos Fire Felt.	
Asbestos	82
Carbonaceous matter not determined	18
Magnesia (Sectional).	
Magnesia	92.2
Fibrous asbestos	7.8
Magnesia (Plastic).	
Magnesium carbonate	93
Fibrous asbestos	7
Asbestos Cement Felting.	
(Probably) Powdered limestone	64.5
Plaster of Paris	3.5
Asbestos	32
Asbestos Sponge Cement Felting.	
(Probably) Powdered limestone	59
Plaster of Paris	10
Asbestos	31
Fossil Meal.	
Insoluble silicate	80
Carbonaceous matter, hair, paper, sawdust, etc.	12
Soluble mineral matter	8

* Manuscript received December 10, 1894.—*Secretary, Ass'n of Eng. Socs.*

The chemical analyses were approximate and were intended only to give some practical idea as to the composition of the different coverings.

The tests were only comparative, and the apparatus consisted of

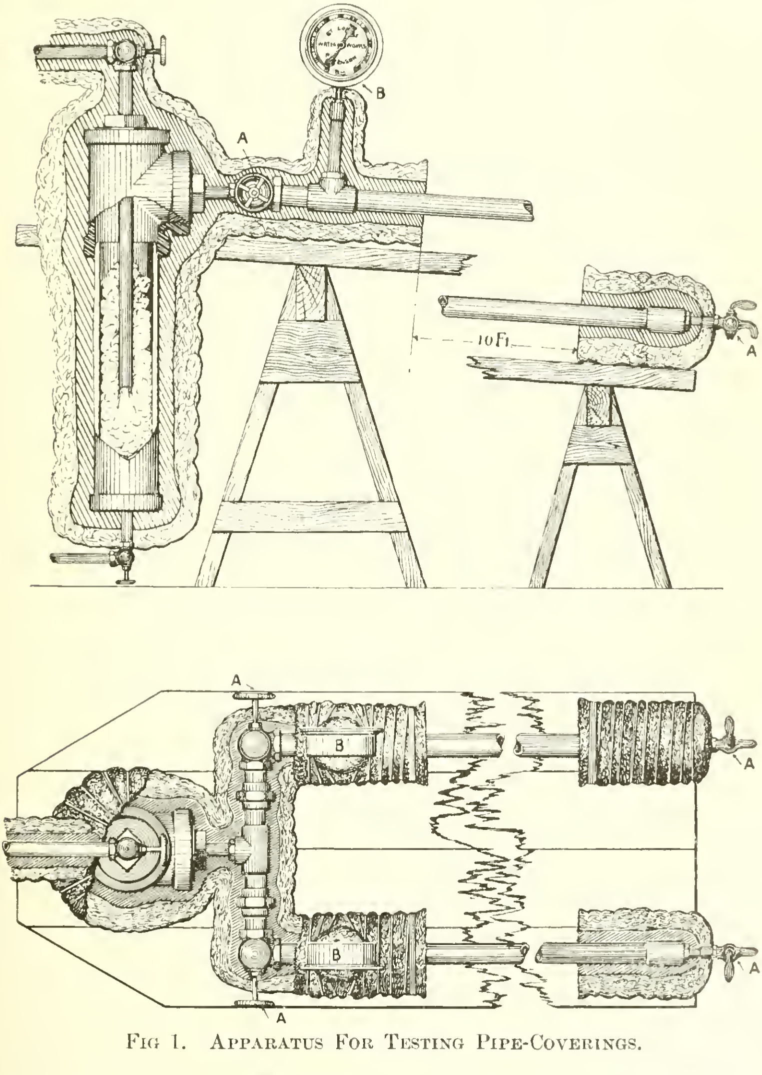


FIG 1. APPARATUS FOR TESTING PIPE-COVERINGS.

two 1-inch pipes about 24 inches apart, connected at one end and set at a slight incline. Fig. 1 gives a general idea of the connections.

The pipe was first put together and tested. All connections, valves and fittings were then covered with 1 inch of plastic magnesia. When

this was dry it was covered with 1 inch of hair felt, bound on with twine. There were left bare on each line 10 feet of 1-inch pipe, to which the coverings to be tested were applied. All the coverings tested were 1 inch thick.

Before beginning a test, steam was allowed to blow through the pipes for some time. Two independent methods of comparing the insulating properties were used. First, by measuring the water condensed in a given time; second, by closing valves at A—A and noting the reduction of pressure on the gauge B at intervals of one minute.

On all condensation tests the gauge pressure was held at 25 pounds. The water was drawn off every fifteen minutes and was measured in cubic centimeters. Each test was continued for four hours. The mean results are tabulated below.

Condensation Tests.

Name of Covering.	C. C. Condensed Per Hour.
Magnesia (plastic)	334.
Magnesia (sectional)	335.3
Asbestos fire felt	367.5
Asbestos sponge moulded	371.3
Fossil meal	376.2
Plaster of Paris and sawdust	438.
Asbestos fire felt cement	563.7
Asbestos sponge cement	604.
Bare pipe	1085.

On all pressure tests the gauge pressure was made 25 pounds at the beginning. Four tests were made of each covering, and the mean results are plotted in Fig. 2.

Both methods show that the magnesia plastic and sectional coverings possess the best insulating powers. Compared with the asbestos fire felt and sponge moulded, the difference is $3\frac{1}{2}$ grams per foot of 1-inch pipe per hour. There will be the equivalent of 6,000 feet of 1-inch pipe in engine and boiler houses at Chain of Rocks.

$$6{,}000 \times 3\tfrac{1}{2} = 21{,}000.$$

$$\frac{21{,}000 \times 24 \times 2\tfrac{1}{4}}{1{,}000} = 1{,}134 \text{ pounds of water per day.}$$

$$\frac{1{,}134}{6} = 189 \text{ pounds of coal per day.}$$

$$\frac{189 \times 365 \times \$.0547}{80} = \$47.20.$$ Saved per year by using magnesia instead of asbestos.

A question which naturally arises, in a comparison like the above, is that as to the durability of the coverings, and I will say that the

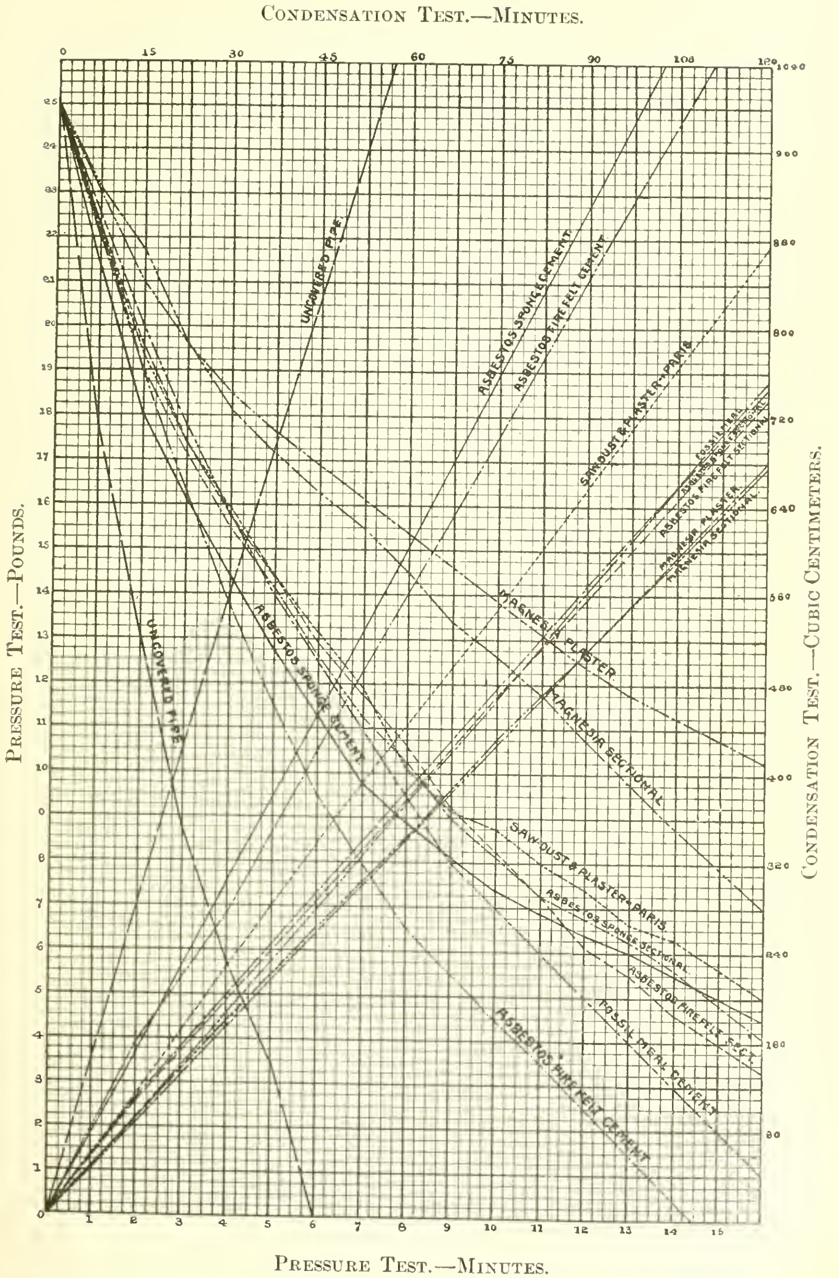

Condensation Test.—Minutes.
Pressure Test.—Pounds.
Condensation Test.—Cubic Centimeters.
Uncovered Pipe
Asbestos Sponge Cement
Asbestos Fire Felt Cement
Sawdust & Plaster-Paris
Magnesia Plaster
Magnesia Sectional
Asbestos Sponge Sectional
Asbestos Firefelt Sect.
Fossil Meal Cement
Pressure Test.—Minutes.

Fig. 2.

magnesia sectional covering, which has been on pipe at Bissell's Point for four years, shows no signs of deterioration; also that the asbestos sponge moulded covering, which has been on pipes at Harlem Creek for less than two years, is becoming soft and the plaster of Paris seems to be reduced back to the original powder, with nothing but the fibrous asbestos to hold it together. Another question is that of steam pressure. The experiments were made at the High Service Station, No. 2, and it was found convenient to have all tests made at 25 pounds gauge pressure. As the working pressure at Chain of Rocks will be at least 125 pounds, the relative efficiency of insulation will be slightly changed, but, in the writer's opinion, not enough to change the conclusions here arrived at. After giving the matter considerable attention and thought, he has no hesitation in recommending the magnesia covering, sectional and plastic, as the best insulation in the market.

THE ST. LOUIS EXTENSION OF THE ST. LOUIS, KEOKUK AND NORTHWESTERN RAILROAD.

Address

By B. L. Crosby, Retiring President of the Engineers' Club of St. Louis.

[Read December 19, 1894.]

The St. Louis Extension of the St. Louis, Keokuk and Northwestern Railroad leaves the old line of the road at a point, *O*, Fig. 1, in St. Charles County, about two thousand feet south of the crossing of the Cuivre River. From this point it runs, for about thirty miles, in an easterly direction, down the long stretch of bottom-land between the Mississippi and Missouri Rivers, locally known as "Missouri Point." It then turns to the south, and crosses the Missouri River at a point about eight miles above its mouth. From the Missouri River it runs in a southerly direction, through the bluffs and uplands of St. Louis County, striking the city limits of St. Louis at a point about half a mileeast of the Bellefontaine Road, and thence down through the Mississippi bottom, and along the river front to a southern terminus at Franklin Avenue, a distance of about forty-eight and one-half miles.

The construction of this extension has been carried through under the direction of Mr. George S. Morison, of Chicago, as Chief Engineer, and the writer, as Resident Engineer, has had charge of the location of the whole line and of all the construction, except the line through Missouri Point. During the time that the foundations of the bridge across the Missouri River were being put in, he was relieved of the charge of the work in St. Louis City and County.

The line was located with maximum gradesof 26.4 feet to the miles and a maximum curvature of 3°, so that the full trains hauled over the old line can be brought through to St. Louis without doubling and without increase of motive power, whereas, during the time that the St. Louis, Keokuk and Northwestern Railroad ran into St. Louis over the Wabash Railroad, a full train hauled to St. Peter's made two full trains from St. Peter's to St. Louis, over the Wabash. This location, of course, involved some pretty heavy work in the broken ground of St. Louis County, but the extra cost will be far more than balanced by the reduced cost of operation.

The line down through the bottom-lands on Missouri Point involved very little work of special interest, being of the usual type of flat prairie work, almost entirely on embankment, raised above the level of any high water, of which there is any record. For about twenty-four mile,

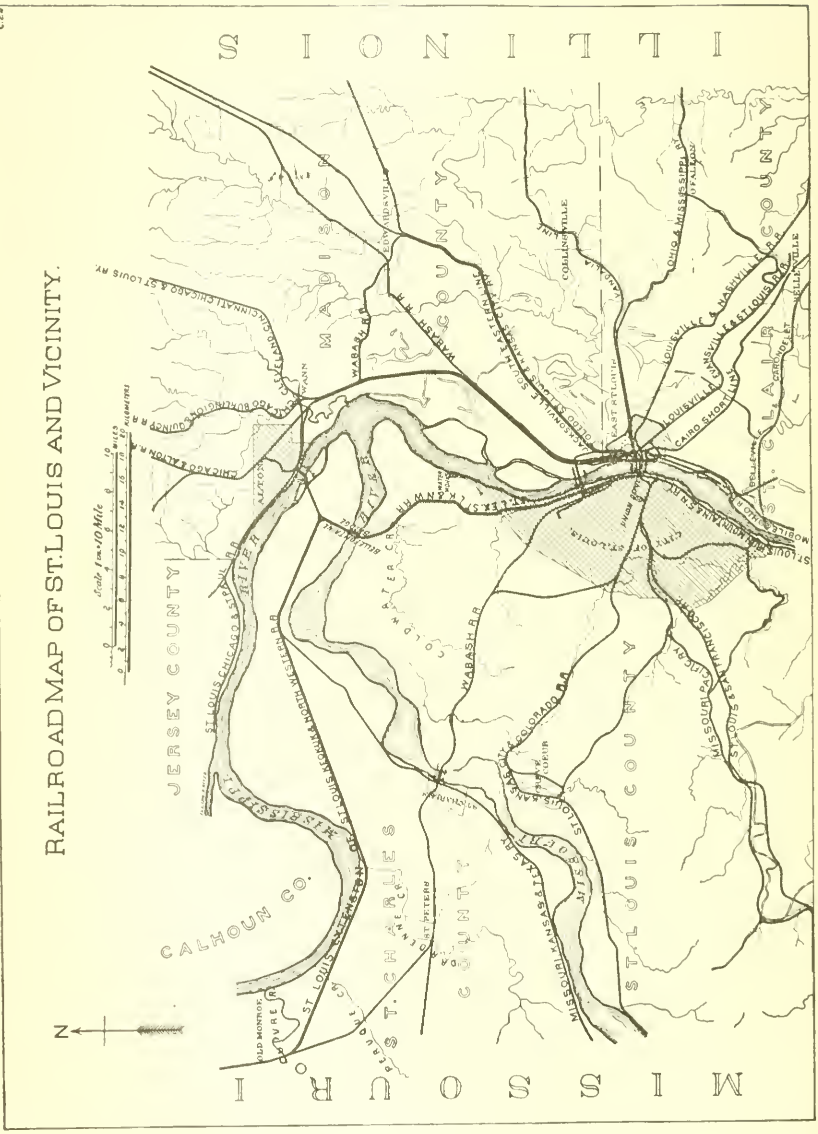

RAILROAD MAP OF ST. LOUIS AND VICINITY.
ILLINOIS
MISSOURI
MADISON COUNTY
ST. CLAIR COUNTY
JERSEY COUNTY
CALHOUN CO.
ST. CHARLES COUNTY
ST. LOUIS COUNTY
MISSISSIPPI RIVER
ALTON
EDWARDSVILLE
COLLINSVILLE
EAST ST. LOUIS
BELLEVILLE
CITY OF ST. LOUIS
WABASH R.R.
CAIRO SHORT LINE
LOUISVILLE & NASHVILLE R.R.
OHIO & MISSISSIPPI RY.
MISSOURI PACIFIC RY.
MISSOURI KANSAS & TEXAS RY.
ST. LOUIS KANSAS CITY & COLORADO R.R.
ST. LOUIS KEOKUK & NORTH WESTERN R.R.
ST. LOUIS CHICAGO & ST. PAUL R.R.
CHICAGO & ALTON R.R.
CHICAGO BURLINGTON & QUINCY R.R.
CLEVELAND CINCINNATI CHICAGO & ST. LOUIS RY.
ST. CHARLES
N

Fig. 1.

from where it leaves the old line, the road was built as single track, but the balance of the line to St. Louis is double track.

Two small streams, Peruque and Dardenne Creeks, are crossed, and the bridges over these creeks have one novel feature, which may be of interest. The bridges are alike, and consist, each, of an 80-foot deck-plate girder, the substructure being of piles driven within cylinders. The cylinders are filled with concrete around and over the piles, and cast-iron caps on the cylinders form the seats for the girders. The novel feature is, that, in order to keep the slopes of the banks away from the cylinders, the girders are continuous over the piers, extending back of them, 10 feet at each end, making a cantilever arm to carry the ends of the stringers extending to the bank. This makes the length of the girders actually 101 feet, over all.

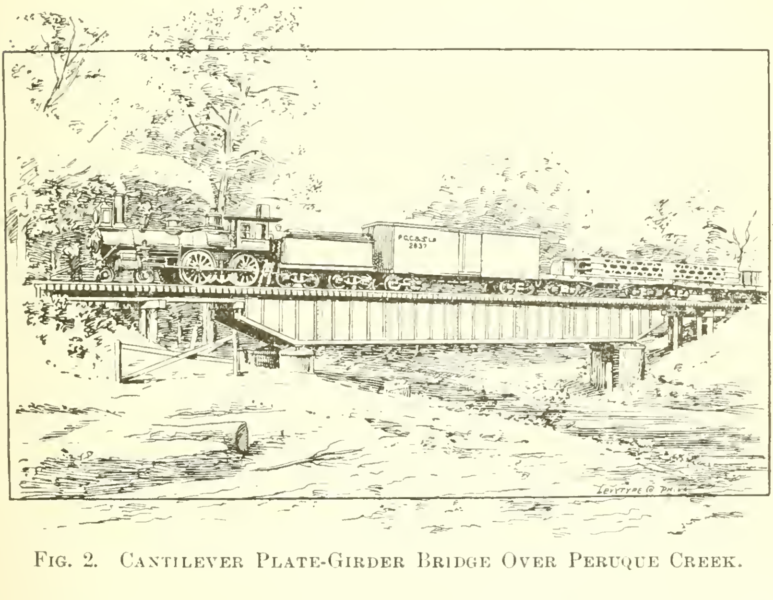


FIG. 2. CANTILEVER PLATE-GIRDER BRIDGE OVER PERUQUE CREEK.

This portion of the line has been ballasted with a light, sandy gravel, but it is intended to ballast this track with burnt clay next spring, and this ballast is now being burned at a point on the line.

The line through St. Louis County has a good deal of heavy work, the heaviest cuts reaching fifty feet in depth.

With two exceptions, all of the county roads are carried over or under the tracks, the overhead bridges generally consisting of timber-bents on each side of track, with roadway stringers of 6 inches x 16 inches, spaced thirty inches centers, and floored with 4-inch hard pine; but at the Bellefontaine Road crossing, on account of the angle at which

the road was crossed, the span was so long that latticed iron girders were used, with 6-inch x 12-inch timbers for floor beams, floored with 4-inch hard pine. Two of the roads are crossed by the tracks overhead, on through plate-girder bridges of 41 feet span. The abutments for these bridges are built of hard-burned brick, laid in Portland cement, with a coping of Romona oolitic limestone, and the foundation is of piles and concrete.

The culverts on the line are, with two exceptions, of cast-iron pipe, 24 inches to 48 inches in diameter.

One of the two exceptions is a 10-foot brick barrel culvert, with foundation and supporting side-walls of concrete. The lower portion of the barrel, where it is supported by the concrete, consists of two rings of brick, and the arch of four rings.

The other, known as the Coldwater Arch, is rather a novel structure. The line of the railroad crosses the valley of Coldwater Creek about fifty feet above the bottom of the creek. The bed of the stream at this point is right on the solid limestone rock, and on the north side was an abrupt bluff of limestone, rising about twenty-five feet above the bed of the creek. It was decided to put in an arch at this point, to carry the creek through, and to build a solid embankment over it. The rock bluff was cut away enough to carry the creek through at right angles to the line of the road, and an arch of twenty feet radius constructed, with one side springing direct from the rock at the bottom of the creek, and the other side from a rough skew-back cut in the rock about 16 feet above the true spring line of the arch, the rock bluff below forming the north side of the culvert. This culvert is 90 feet in length; the arch, built of hard-burned brick, laid in Portland cement, is 36 inches thick; the haunch walls are built of Louisville cement concrete; the head walls at each end are of brick, with Romona stone copings; and the wing walls are of heavy rubble masonry, set in Louisville cement, and having copings of Romona stone.

The line, through both the city and the county, is ballasted throughout with broken stone. On the line in the city of St. Louis there are several interesting pieces of work.

Just south of the city limits the new water works conduit is crossed by means of a bridge consisting of three through plate girder spans, each 73 feet 6 inches over all, supported on two piers and two abutments built of hard-burned brick, laid in Portland cement, on foundations of piles and concrete, with copings of Berea sandstone.

About two miles south of the city limits we reach the north end of the main freight yards, which extend to Grand Avenue, about two miles further south. About five hundred acres of land here are owned by the railroad company, giving it abundant room to increase its yard capacity,

as business may require. At present about twenty miles of track have been laid in this yard, which is so laid out that it can be used as a gravity or poling yard, if so desired. At its north end are located the round-house, coal chute, sand house, oil house and storehouse. The round-house is a brick structure built on a forty-stall circle, but only thirty stalls have been built. The turn-table, 66 feet long, is of steel.

The northern half of the yard is crossed by Harlem Creek, which, after passing under the new water works conduit in Hall Street, originally wandered around in a very irregular course on its way to the river. As so many tracks would have to be carried over this stream, it was considered best to change the channel and to run the creek straight from Hall Street to the river. Borings were accordingly made, which showed that rock for foundation could be found at a depth of from twenty to twenty-four feet below the surface of the ground, and above low water in the river, so that there would be no serious difficulty in excavating to the rock, at the proper season. It was decided to build an arched culvert to carry the creek, and for the present, to build the arch only under the property embraced within the limits of the present yard.

This culvert, or sewer, is I think, the largest in area of any in this country. The bench walls are placed 30 feet apart and are built of Romona limestone, laid in Portland cement and backed up with Louisville cement concrete. The spandrels also are of Louisville concrete. The bench walls, up to the spring line of the arch, vary in height, according to the elevation at which the rock was found, from 6 to 11 feet; the face stones average 2½ feet in depth from the face, with headers every third stone, not less than 3½ feet in depth from the face, and the top course is cut in the form of a skew-back to receive the arch. The back of the wall has a batter of one in eight.

The bench walls were built for the whole distance from the edge of the Mississippi River to the western limits of the company's property, at Hall Street, a distance of 1,560 feet, and they have since been continued by the city of St. Louis to connect with the water works arch over Harlem Creek The arch is built of hard-burned brick laid in Portland cement. It consists of seven rings, with a total thickness of about 32 inches. This arch is segmental, with radius of 16 feet and a rise of 11.43 feet. As above stated, the arch was turned only within the limits of the yard as now constructed, a distance of 607 feet. The ends were left toothed out, so that at any time the arch may be continued, the bench walls being already built to receive it.

The quantities of material in this culvert, and the cost, are as follows:

Earthwork,	74,144	c. y., at	$ .40	$29,657 60
Concrete,	6,068.01	" "	4.75	28,823 05
Face stone,	2,145.88	" "	12.00	25,750 56
Brick masonry,	2,515.82	" "	11.50	28,931 93
Difference in cost between Portland cement and Louisville, used in leveling up foundation under face stone of bench walls				453 05
Total				$113,616 19

In explanation of the apparently high price paid for excavation, I would say that it was very wet work, that a considerable portion had to be handled with derricks, and further, that the price included the refilling over the arch, and distributing the balance of the material where it was needed for filling the yard.

The next important piece of work is the Mound Street Yard. This yard contains about fifteen acres, and is located between Tyler Street on the north, Mullanphy Street on the south, First Street on the east and Second Street on the west. This yard is for the shipment of car-load freight, and has track room for about four hundred cars, each of which is accessible by teams. The driveways between these tracks are all paved, some with granite, but the larger portion with vitrified brick, of which I will later speak more fully. A passenger station, located at the southwest corner of the yard, is at present used for the suburban trains of the Keokuk, and for all trains of the Missouri, Kansas & Texas. The latter railway enters the city over the tracks of the St. Louis, Keokuk & Northwestern. On the west side of the yard is located a five-stall engine house, with turn-table and coal chute. Before work was commenced on this yard, the ground sloped with a grade of about 6 feet per 100 from Second Street to First Street, and from Brooklyn Street to Mullanphy Street nearly all of the ground was covered by buildings. The territory embraced within the limits of the yard was crossed by three streets.

An ordinance was obtained from the city of St. Louis, vacating these streets in consideration of the construction and maintenance by the railroad company of a bridge across the yard from Second Street at the foot of Mound Street, and an inclined drive-way leading from the bridge to First Street at Brooklyn Street. This bridge was constructed in 1891. It consists of a steel span of 293 feet, supported on brick abutments, with Bedford stone coping. The eastern abutment where the turn onto the incline is made, was built hollow, and it serves as a storehouse for material used about the yard. The incline is a timber structure, with a grade of 6 feet in the hundred. Both bridge and incline are paved with pine blocks.

After the construction of the bridge the whole area of the yard was

graded down to the level of First Street, leaving the elevation of the yard about 20 feet below that of Second Street, except at the extreme northern end.

Second Street is supported by a substantial retaining wall, built of Louisville cement concrete, with a facing of a single thickness of hard brick, laid in Portland cement, the brick being laid in Flemish bond, so as to tie the facing back into the concrete. The wall is finished on top with a heavy coping of Bedford limestone, surmounted by a substantial iron gas-pipe railing. This wall was built with a vertical face, and the back is stepped out as required by the depth. It was founded on rock for the whole length. This form of construction, which gives a smooth neat wall, has proved very satisfactory.

In making the excavation, rock was found in the southern and western half of the yard, and over fifty thousand yards were taken out. Nearly all of this was crushed and used for ballasting the yard and main line tracks. About ninety thousand yards of the earth excavated were used for filling a deep quarry which occupied the eastern half of the block between Brooklyn and Mound Streets, and the balance for embankments on the line north of Wright Street.

As above stated, the drive-ways in the yard are largely paved with vitrified brick. This, I believe, is the first pavement of the kind laid in St. Louis, certainly the first of any extent. There are about 16,400 square yards of this pavement. About one-half consists of one course of vitrified brick laid on edge on a foundation of 8 inches of Louisville cement concrete, a sand cushion 1½ inches thick intervening between the brick and the concrete. The remainder consists of two courses of brick, the lower course laid flat on 2 inches of sand, with which the spaces between the bricks were thoroughly filled. This course was then covered with a sand cushion 1½ inches thick, on which the wearing course of brick was laid on edge.

In both cases, after laying, the pavement was thoroughly rolled with a heavy roller. It was then carefully examined and all broken and defective bricks were replaced with sound ones. The pavement was then again rolled and all interstices between the bricks were filled as thoroughly as possible with sand. A layer of sand about ½ inch in depth being finally spread over the top, to be worked in by the travel. For both classes of this pavement the ground was prepared by rolling, and, where filling was required, cinders were used, as being the best material available for that purpose. The cinders were thoroughly compacted by rolling with a heavy roller, all low spots being brought up to grade and re-rolled. In this part of the work the greatest care was used to insure a good foundation. The vitrified brick came from Galesburg, Illinois, and seemed carefully made and thoroughly burned. In the

double-course pavement, the lower course was laid with seconds. It has now been in use since March 4th of this year and has proved entirely satisfactory. Being laid in a yard devoted to heavy teaming, it is subjected to a severe test, and I believe it will stand it. In doing the work thus thoroughly throughout the object has been partly to furnish a test piece, and I think the municipal authorities should watch this pavement with interest, and appreciate the work of the company in making this experiment for them.

At Franklin Avenue and First Street, and extending north to Carr Street, is located the freight house of the company. At the South end, facing Franklin Avenue, is the office building, 141 feet 6 inches front and 38 feet deep, built of brick, laid in Portland cement. The floors are of mill construction, carried on iron girders, except the first floor, which is granitoid, on brick arches turned between the girders. The walls are made of sufficient strength for a seven-story building, in case it should ever be required, but only four stories have thus far been constructed. Just north of and adjoining the office building is the freight house proper, an iron frame building with foundation of stone and brick, 770 feet long and 131 feet 10 inches wide, with five tracks in the house, giving a capacity of one hundred cars. The delivery platform is on the east and the receiving platform on the west side. Owing to the difference in the level of the streets on the two sides of the freight house, it was necessary to build the platforms on a grade sloping towards the east, but, as everything is handled to and from the cars down this grade, this has proved rather a benefit than otherwise. North of the freight house, and extending to Carr Street, are open platforms, with granitoid floors, 76 feet long, each provided with a crane for handling heavy articles, such as machinery and boilers. Just north of Carr Street is a small yard, with a capacity of thirty-two cars, for handling car-load freight, and the drive-ways of this yard are also paved with vitrified brick.

The most important structure on the line of the St. Louis Extension is the Bellefontaine Bridge, across the Missouri River. This is a double track bridge, with four main spans of 440 feet each, center to center of end pins: supported on heavy masonry piers, and with a viaduct approach, 850 feet in length, on the north side of the river. Beyond the approach is a timber trestle, 2,960 feet in length, which is now being filled in. The main river spans are single-intersection Pratt trusses, divided into eight panels of 55 feet each. The trusses are designed for a rolling load of 3,000 pounds per foot on each track. These spans are built without any adjustable members, the top and bottom laterals are all riveted, and the reversal of strains at the centers of the trusses is effected by so constructing the inclined web members that they shall resist compression as well as tension, instead of using the usual adjust-

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CROSBY--ST. LOUIS EXTENSION OF THE ST. L., K. & N. W. R. R.

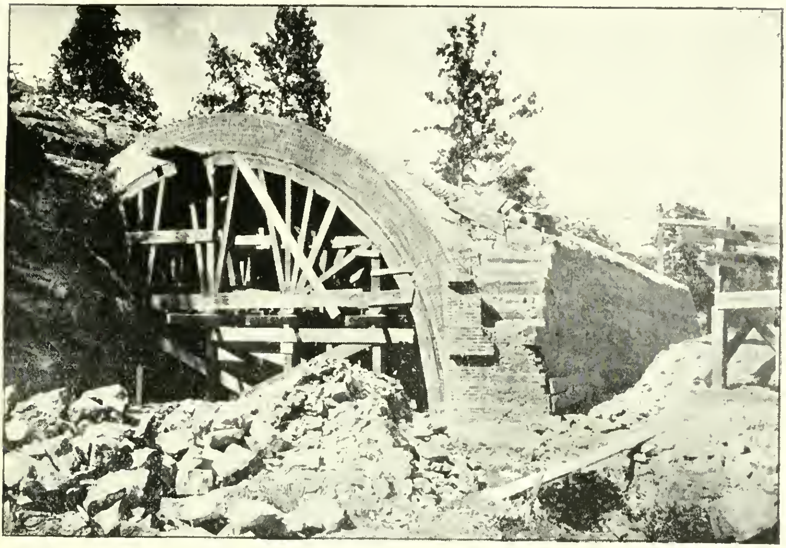


Fig. 3.—Coldwater Arch, August 20, 1893.

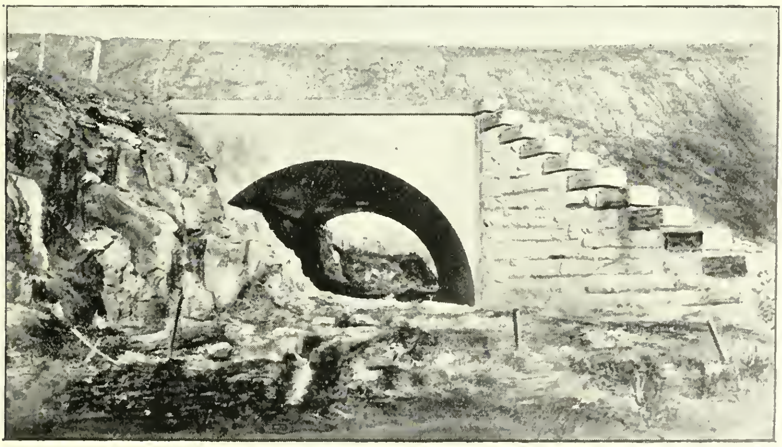


Fig. 4.—Coldwater Arch, December 14, 1894.

CROSBY—ST. LOUIS EXTENSION OF THE ST. L., K. & N. W. R. R.

Fig 5.—Bellefontaine Bridge across Missouri River.

able counter ties. These spans are built throughout of steel, except the bed plates on the piers, which are of cast iron. The steel work was manufactured by the New Jersey Steel and Iron Co., of Trenton, N. J., and erected by Wm. Baird, of Pittsburg.

The viaduct approach is a riveted steel structure, with alternate spans of 28 feet 6 inches and of 32 feet 2 inches. It rests on small piers of brick, which will be described later. The steel work of the viaduct was furnished and erected by Messrs. A. & P. Roberts & Co., of Pencoyd Iron Works, Philadelphia.

The substructure for the main bridge consists of four piers and an abutment. This abutment is founded on solid rock on the south bank of the river at about the level of extreme high water. The piers are all founded on pneumatic caissons, which are, with one exception, sunk to the bed rock of the river. They are numbered from south to north, the abutment being Pier I.

The masonry of the piers is built of oolitic limestone from Bedford and Romona, in Indiana, except that in Piers II, III and IV, for about thirty feet, covering the range between extreme high and low water, the face stones are of Minnesota granite. All of the face stones are set in Portland cement. The backing consists of large stone, cut to the same rise as the courses in which they are laid, and with both top and bottom beds dressed. The specifications required that the spaces between these large backing stones should occupy not more than 20 per cent. of the area inside of the face stones; but, in fact, as the masonry was laid, they occupy in most instances not more than 10 per cent. of that area. All such spaces were filled with concrete, thoroughly rammed into place. These backing stones were so laid as to break bond in the different courses. The backing was laid in Louisville cement mortar, except in freezing weather, when Portland cement was used throughout. After the masonry in the piers was laid, all face joints were cleaned out to a depth of 1½ inches, and pointed with Portland cement mortar, in the proportion of 1 part cement to 2 of sand, driven in with calking irons. The masonry of these piers is a very fine piece of work, and, I think, the best I have ever seen.

The work was done, under contract, by Messrs. Christie & Lowe, of Chicago; Mr. George A. Lederle was the resident partner. The contractors furnished all materials and tools, except cement, which was furnished by the railroad company. There were 11,022 yards of this masonry, and there were used in setting it 1,620 barrels of Portland cement and 1,566 barrels of Louisville cement. The price paid the contractors was $17 per cubic yard, and the average cost, including everything, was $17.75.

All of the foundation work was done by the company's men, under

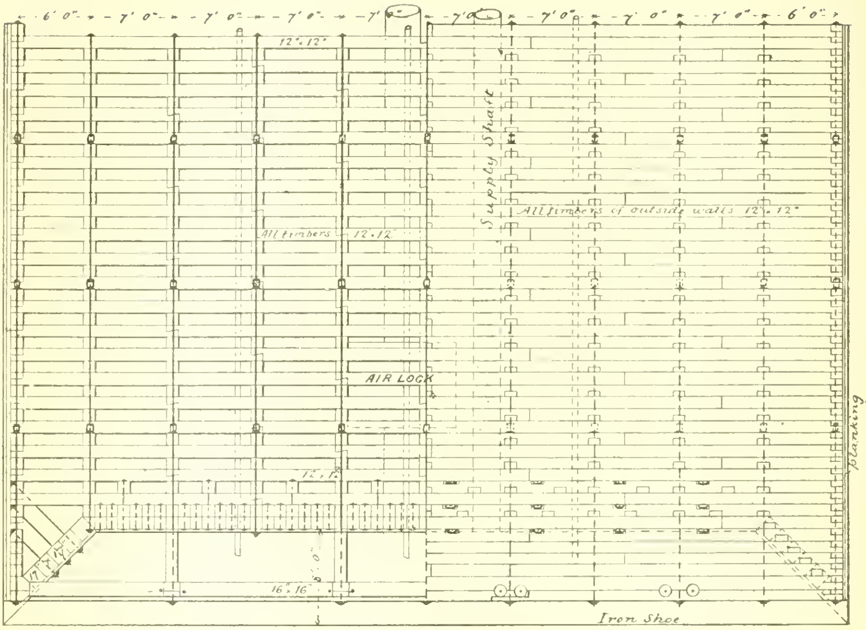


Fig. 6.

Longitudinal Section at Centre.

Side Elevation under Planking.

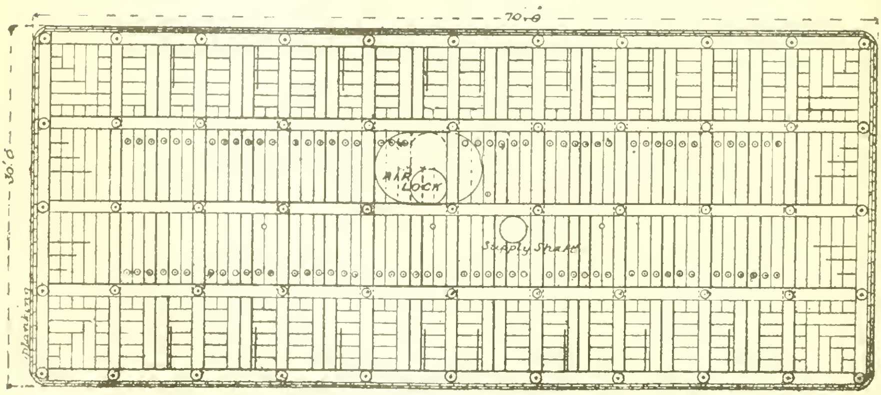


Fig. 7.—Plan on Top.

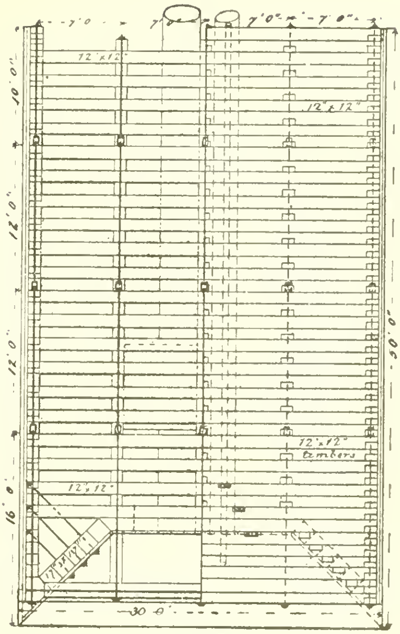


FIG. 8.

CROSS-SECTION AT CENTRE. END ELEVATION UNDER PLANKING.

FIGS. 6, 7 and 8.
CAISSON AND CRIB WORK
OF CAIRO BRIDGE.

the direction of the Resident Engineer. The work was handled under rather more than ordinary difficulties, owing to the fact that during the greater part of the time that the foundation work was in progress there was no railroad communication with the bridge, and all material and supplies had to be brought up the river on barges, which added considerably to the expense and was a constant source of worry to those in charge of the work, especially during the extreme low stage of water which prevailed in the fall of 1892. To prepare for the early winter, when the river was liable to be blocked with ice, a large supply of coal had to be procured and stored; and, notwithstanding the precaution taken in this direction, there was less than ten hours' supply on hand when the track from the north finally reached the bridge in January, 1893, so that coal could be received by train.

There being no town or village in the neighborhood, it was necessary to erect boarding-houses and all other buildings required for the accommodation of the men and for the storing of materials.

The four piers in the river are founded on pneumatic caissons, those for Piers II, III, and IV being 70 feet long by 30 feet wide, and that for Pier V, 60 feet long by 24 feet wide. They are identical, in construction, and in form, except as to height, with those used at the Cairo bridge, and illustrated in Figs. 6, 7 and 8, reproduced from Vol. IX, No. 6, of this JOURNAL, June, 1890, pages 314 and 315.* All the caissons were 16 feet high, including the iron cutting edge, and were surmounted with a wooden crib-work, constructed like the upper portion of the caisson proper. This crib-work was 24.4 feet high in Pier II, 45 feet in Pier III, 58 feet in Pier IV, and 64 feet in Pier V. The crib-work was filled with concrete, Louisville cement being generally used in the proportion of 1 part cement, 2 of sand, and 4 of crushed stone; but, in certain portions of the work, and at all times in freezing weather, Portland cement was used, generally in the proportions of 1 part cement, 3 of sand, and 5 of crushed stone. The form of caisson employed was that which has generally been used by Mr. Morison on his works, with an iron cutting edge, vertical outside walls of 12 by 12-inch timber, and the working chamber walls inclined inwards on an angle of 45°, supported by iron rods running through the outside walls. In the larger caissons, there were in the working chamber four transverse braces of 16 by 16-inch timber, and also a longitudinal timber of the same size. In the smaller caisson, the longitudinal timber was omitted, and there were only two transverse timbers. The inside of the chamber was lined with 3-inch plank, and then carefully caulked. The caissons throughout were built of long-leaf yellow pine.

* These cuts are kindly furnished by Mr. John W. Weston, ex-Secretary, Ass'n Eng. Socs.—*Secretary.*

The pneumatic plant used for sinking the caissons consisted of two No. 4 Clayton duplex compressors, having steam and air cylinders, each 14-inch, with 15-inch stroke; a Worthington duplex pump, $18\frac{1}{2}$ by $10\frac{1}{4}$ by 10 inches, and a small dynamo, run by a Westinghouse automatic engine for lighting the working chamber. This plant was set up on the steamer John Bertram, whose boilers furnished the power to run the plant. There was also a duplicate plant, which was used during part of the work on Piers II and III, when there was not water enough to reach those piers with the steamboat. This plant was erected on a platform, supported on piles just below Pier III. In addition to the above, there were several hoisting-engines, a pile-driver boat, provided with a derrick for handling the timber in building up the crib-work and an arc-light plant for night work. As far as possible, the concrete was mixed by machine, a Cockburn barrow mixer being used, which was set up on a large barge, with a derrick for handling the concrete buckets. Several other barges for handling timber, cement and crushed stone were provided, and a small steamboat for towing the barges.

A short account of the work on some of the piers, and of some of the difficulties encountered, will probably be of interest. All of the caissons, except that for Pier II, were built on launching ways on the north side of the river just above the bridge line. These launching ways were constructed by driving piles, which were capped with 12 by 12-inch timber running up and down stream, and then the way timbers, also 12 by 12, were put in position and securely drift-bolted. The ways had a slope toward the river of 3 inches to the foot, and were extended out into the river far enough to allow the caisson to float before being clear of the timbers. The piles under water were cut off by a circular saw hung in a frame attached to the leads of the pile-driver, the caps were set in position by a diver, and the drift-bolts, which had been started into the caps before they were sunk, were driven by a ramrod working through a gas-pipe placed over the drift-bolt.

The cutting edge for Pier III was set up on July 30, 1892, and the building of the caisson proper was completed and the caisson successfully launched on August 20th. In the meantime, sandbars had formed at the site of the pier, so that there were only from two to five feet of water, and the caisson, after launching, drew ten feet. However, it had to be got into position, if possible, and this was accomplished as follows: The steamer John Bertram was taken over to the pier site and made fast to piles driven for that purpose, and her wheels were set to work to wash out the sand. This proved a success, a hole from seven to ten feet deep being dug out at the site of the pier. In the meantime, barges had been placed on each side of the caisson, and heavy timbers bolted across the caisson, and extending out over the barges. On the morning of

August 3d, the John Bertram was brought back to the shore, and fastened behind the caisson, which it proceeded to tow across the river until it struck bottom, when the air pumps were started and air pumped into the caisson, raising it until it drew only about five feet of water. As the caisson was raised, blocking was placed under the timbers projecting over the barges, to keep it level, and without further difficulty it was towed to its proper position, the air was released and the caisson was let down upon the sand. After this, the work was carried on without further difficulty, except that the caisson was abandoned from September 21st until December 3d, while the second plant was being erected, the water at the pier having become so shallow that the steamer had to be removed on the former date. This caisson finally reached the bed rock on January 2, 1893, at a depth of 88.80 feet below standard low water. The work of filling the chamber with concrete was completed on January 11th. The material was excavated and discharged from the working chamber by the Morison sand pump, a modification of the Eads sand pump used on the St. Louis Bridge. On this pier, and also on Pier IV, an elevator was provided for taking the men up and down the shaft. The air lock, Fig. 9, was placed at the top of the caisson proper, with a short shaft leading down into the chamber. Above the lock was a shaft six feet in diameter, provided with guides, on which the elevator ran, being raised and lowered by an engine placed on top of the shaft, and driven by the compressed air taken from the caisson. This elevator proved a great relief to the men, and it would have been a great convenience if we had had one on each of the piers.

The caisson for Pier IV was launched on September 20th, and on the 24th the caisson was towed out into position and securely fastened to four clusters of anchor piles, near the four corners. By means of lines leading from these clusters of piles it was held accurately in position as it sunk down to the sand. When the caisson was placed in position on the 24th, soundings showed fourteen feet of water at the west end and thirteen feet at the east end. The work of building up the cribbing was started that night, and continued till the 29th, when concreting commenced. At this time, soundings showed about twenty feet of water all around the caisson, which was still afloat. As the weight of the concrete settled the caisson, the current gradually cut away the sand below; and on the morning of the 30th, there was an average of twenty-three feet of water all around, with 25.5 at the northwest corner. At about 3 P.M. of that day the caisson grounded on the south side, and on the morning of the 1st of October, it was still aground on the south side, but on the north side there were about twenty-five feet of water, with twenty-six feet at the northwest corner. About six hundred bags of sand were thrown in at the west or up-stream end, in order to cut off

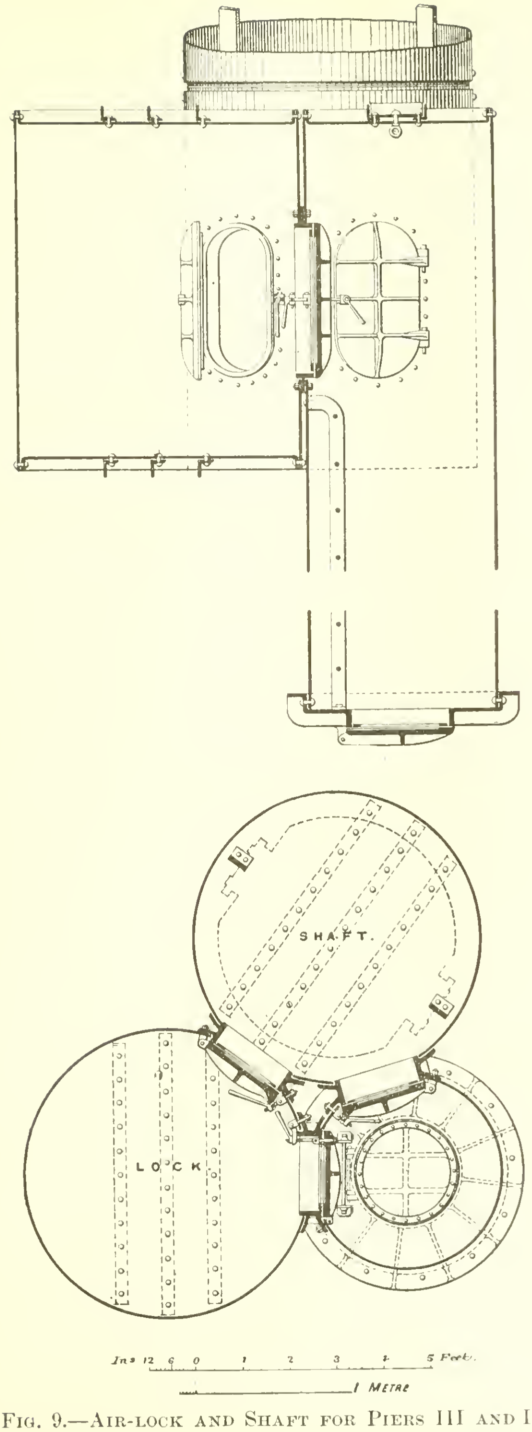


FIG. 9.—AIR-LOCK AND SHAFT FOR PIERS III AND IV.

the current, and with some success, for on the morning of the 2d, the caisson was found to be aground on sacks at the west end. Concreting was continued during the 2d and 3d, and during the afternoon of the 3d more sand bags were thrown in along the north side, as the sand had again started cutting there. On the morning of the 4th, the air pipes were connected and the air pressure was put on.

On attempting to enter the caisson through the air-lock, the door of the main shaft below the lock was found to be blocked up underneath, so that it could be opened only a few inches, and it was impossible to enter in that way. The pressure was let off the caisson, a man was lowered into one of the supply shafts used for taking in the concrete filling of the chamber, the top was put on the shaft again and air pressure was once more turned on the caisson. The man sent into the caisson found that a part of the temporary false bottom that had been used in launching it, had not been removed, and that some of the timbers were jammed up against the main shaft door. These he soon cleared away and the caisson could then be entered through the lock. The writer went down to make an examination, and found that along the south side and east end the caisson was filled with sand nearly to the roof, while along the north side and west end it was far below the cutting edge. Some of the false bottom had become wedged under the cross-beams, and as weight was put on the caisson above it was pressed down, and the cross-beams supported most of the weight of caisson and concrete; the result being that all of the cross-beams were split and most of the vertical posts between them and the roof were either shoved up into the roof or down into the beams, the worst point being at the second cross-beam from the down-stream end, where the beam was shoved up so that the distance between it and the roof was only 3 feet 4 inches, instead of 4 feet, as originally built. The vertical post at the center was split through its entire length, and crushed down into the longitudinal beam.

Concreting was at once stopped, so as to add no further weight, and men were set to leveling down the sand in order to bring the bearing on the cutting edge all around, and to clear out under the beams, so as to relieve the pressure on them. When this was done, the beam that had been pushed up eight inches came back to within three inches of its original position. As soon as everything was cleared up the cracked beams were jacked down into place and securely bolted, new posts were put in alongside the old ones that had been damaged, and the work went on as usual. On November 18th this caisson reached the bed rock at a depth of 101.1 feet below standard low water, and the concrete filling was completed on the 30th. In this pier, on top of the bed rock, was found a layer over two feet deep of cobble stones and boulders, most of which were worked into the concrete, but had to be handled so much

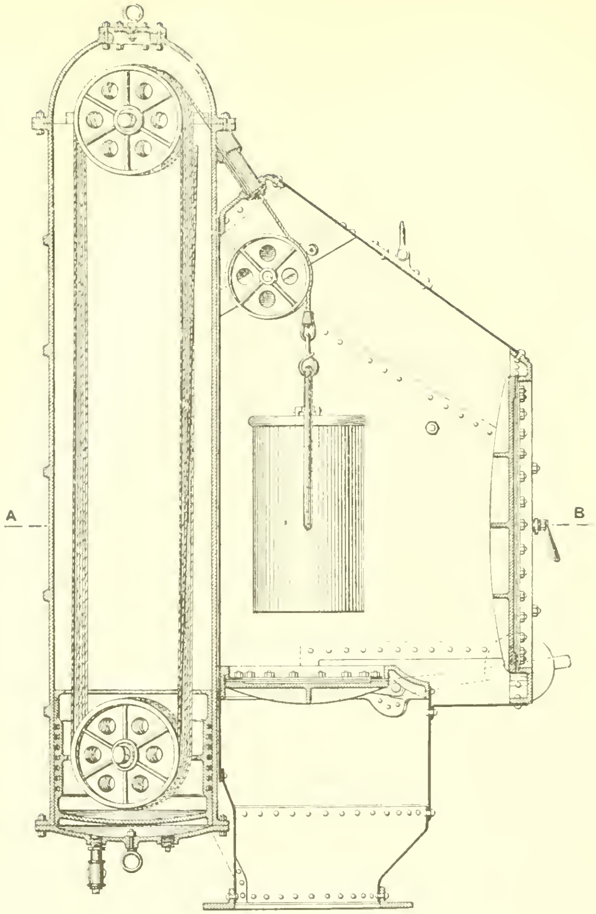
that they made the work of concreting slow and expensive, especially as the men were working about one hour at a shift, and from two to three hours for a day's work, at $3.50 per day.

The caisson for Pier V was launched December 11th, and reached its final resting-place, 82.6 below standard low water, on March 7, 1893. It was not sunk to bed rock, but was stopped in sand. As it comes within the permanent shore line, where the caisson will always be surrounded with sand, so that there can be no danger of scour, it was considered perfectly safe to leave it on the sand. The rock at this point was 109 feet below low water, and we would have had to work with a submersion of at least 112 feet. It was, therefore, not considered best to take the additional risk where it was not really necessary. The total weight of this pier, taking the timber at 50 pounds per cubic foot, concrete at 145 pounds, and masonry at 160 pounds, which weights, I believe, to be rather in excess of the actual, is :

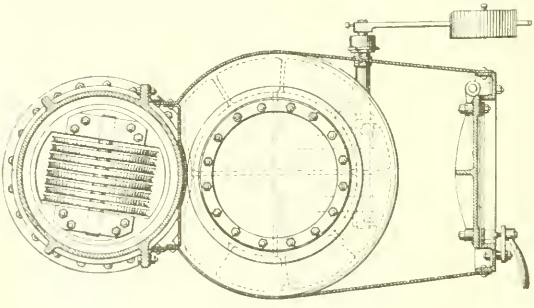
	9,864	tons.
It carries one-half of the 400 foot span	700	"
Making a total, with bridge unloaded, of	10,564	"
With both tracks loaded with 3,000 pounds per foot. . . .	660	"
We have in all	11,224	"
From this should be deducted the weight of water displaced, or	3,784	"
Leaving	7,240	"

which, on the bottom area of 1440 square feet, would make a pressure of practically five tons per square foot, which is not excessive. This is figured at standard low water, and no account is taken of the friction on the sides of the caisson. If this is taken into account, the pressure on the bottom of the foundation is reduced to a very low amount.

The caisson for Pier II was built in position on the sand bar. Borings made at the site of this pier showed that the bed rock dipped to the north about seven feet in the width of the caisson, making it necessary to excavate and hoist a considerable portion of the rock. For this purpose a Morison clay hoist, Fig. 10, was provided. This hoist was originally designed for use on the foundations of the bridge over the Missouri River at Rulo, Nebraska. It employs an air-lock set on top of the concrete supply shaft. On the back of this air-lock is bolted a cylinder with a diameter of 18 inches and stroke of about 9 feet, connected with the air-lock near the top by a pipe 3 inches in diameter. In the top of the cylinder is placed a set of sheaves, and in the top of the piston, which is in the cylinder, is fastened another set of sheaves. Over these sheaves is run a wire rope, which is then led through the connecting



SECTION THROUGH CENTRE.



SECTION AT A.B.

FIG. 10.—MORISON CLAY-HOIST.

pipe to the air-lock and over a sheave which hangs over the center of the shaft. The bottom door of the air-lock is hung on a shaft, which passes out through a stuffing box in the side of the lock so that the door can be worked from the outside. The bottom of the cylinder is connected with the air pipe of the caisson by pipes provided with the necessary regulating valves. A bucket being hung on a hook at the end of the rope, the outer door of the lock is closed and the air pressure is let into the lock until it is equal to that in the caisson below, when the bottom door is opened from the outside. Air pressure is then admitted to the cylinder and as the air pressure under the piston is equalized with the pressure in the caisson the weight of the bucket overhauls the piston and the bucket is lowered to the bottom, where a full bucket is hooked on and hoisted by allowing the air to escape from under the piston, when the caisson pressure on the top of the piston, which comes back through the connecting pipe, forces the piston down and raises the bucket, the bottom door being closed, the pressure in the lock is equalized to the normal pressure, the door is opened and the bucket is dumped.

The sinking of this caisson presented no difficulty, except that occasioned by encountering some oak logs, until rock was reached on the south side, at a distance of 62 feet below standard low water, through which the caisson was carried down to a depth of 68.4 feet below standard low water. On the north side the cutting edge did not reach the rock, except for a short distance near the northwest corner, but blocking was put under the shoulder of the cutting edge to support the caisson, and the rock was entirely cleared off, so that the concrete filling was placed on the entire surface of the rock. At the northeast corner of the caisson the concrete was carried down to a level more than two feet below the cutting edge. The writer personally superintended this piece of work, and he knows that it was thoroughly done. The rock was broken up by blasting. The explosive used was rackarock, which has an advantage over dynamite for such work in not producing the violent headache which the latter generally causes, especially in a confined place like a caisson. To avoid danger of damaging the caisson, only light charges were used, and the explosive proved satisfactory.

During the filling of the chamber with concrete there was a sharp rise in the river, which completely submerged the pier, only the shafts and pipes being left above water; and they were protected from injury from drift logs by a bulwark of bags of crushed stone built up on the nose of the pier and carried down to and around the shafts. During the last day or two the water was five feet deep over the masonry of the pier.

There were used in the construction of these caissons 1,608,814 feet

B. M. of yellow pine timber. The cost of framing this timber and building it into the caissons averaged $21.93 per M. B. M. This includes cost of launching ways and of material and labor of all kinds, except the cost of the timber itself. It includes also all handling and towing.

There were placed in these caissons 13,285 cubic yards of concrete, in which were used 4,759 barrels of Portland cement and 16,035 barrels of Louisville cement. The average cost of this concrete, including all material and labor, was $5.36 per cubic yard. The average cost per cubic foot of caisson and filling, including cutting edges, shafting, etc., was 34.2 cents. The average cost of sinking was 9.17 cents per cubic foot sunk, this average being materially increased by the cost of the rock excavation in Pier II, the average cost for that pier being 12.33 cents. The average per vertical foot sunk was $177.99. Pier II affected this average also, as it cost $258.94, while Pier V cost only $116.17 per foot sunk.

The piers for the viaduct approach were built of vitrified brick laid in Portland cement, and were finished with heavy cast-iron caps. These piers are circular, with a diameter of 5 feet, and they rest on a foundation of Portland cement concrete supported on seven oak piles extending 3 feet into the concrete. This concrete foundation was 5 feet deep, built in the form of a hexagon, with sides of 5 feet. The brickwork was 8 feet in diameter, where it started from the concrete, and tapered to 5 feet in a rise of 3 feet 10 inches. The anchor rods were made in the shape of a U, and extended down through the brickwork and for 3 feet into the concrete. At the north end of the viaduct was built a small masonry pier of Romona limestone. This pier rested on a foundation of Portland cement concrete 10 feet thick, supported by 40 oak piles, which extended 6 feet up into the concrete. With the exception of the limestone masonry, this work was all done by the company's men, under the direction of the Resident Engineer.

The cost of pile driving, including unloading and distributing piles, and all fuel, rope, and material of all kinds, was 21½ cents per linear foot. This rather high cost was largely due to delays in waiting for piles.

The cost of the concrete was $8.48 per cubic yard, including all labor and material and the necessary forms used. This cost is also high, but the mixing was all done by hand, and the material had to be hauled a long distance. It was carefully put in and it can be relied upon.

The timber trestle was also put in by the company's men. As this trestle was to be filled immediately, the specification for the timber was not very rigid, no objection being made to sap, but it was required to be sound and free from wane. Soft wood piles were used. With this exception the trestle was built as if it were to last for years, and was very

thoroughly braced, both longitudinally and transversely. There were 1,437,763 feet B. M. of Southern pine timber used in this trestle, 97,552 pounds of iron and 35,220 linear feet of piles.

The cost of unloading, handling and driving piles, including all material and labor, except the cost of piles themselves, was 13.7 cents per linear foot.

The cost of unloading, framing and erecting timber, including all material and labor, was $7.42 per M. B. M.

In addition to the work described there was considerable work done on shore protection. This included the revetment of about 2,000 feet of bank above the bridge, with a woven willow mattress, which was from 125 to 200 feet in width. This mattress was sunk and covered with riprap. Before weaving the mattress, the bank was prepared with a slope of three to one, the excavation being done by hydraulic grading and the power being furnished by the Worthington pump on the steamer John Bertram. This proved a very satisfactory and economical way of doing the work, and I regret that I am unable to give any exact figures of the cost. The shore protection also included a pile dike, about 1,100 feet long, extending down past and outside of Pier V. The piles were driven through a sill mattress 100 feet wide, extending 75 feet outside of the piles. This mattress is built in the form used by the United States Government Engineers on the lower Mississippi River, being composed of fascines of brush between frames of poles, and the whole is securely fastened with wire. This dike has withstood a flood which was up to the tops of the stringers, and with the strongest current in the river running along it. Those familiar with the Missouri will know that without the sill mattress the piles would not have stood an hour.

The first engine passed over the bridge on December 27, 1893, and the structure was opened for traffic on March 4, 1894.

MEASUREMENT OF WATER.

Report to the Montana Society of Civil Engineers.

By A. M. Ryon, Committee on the Measurement of Water for Irrigation and Mining.

[Read November 10, 1894.]

In the early days of mining and farming in this State, as in others, some easily applied approximate method for the measurement of water was found to be necessary; for this purpose an orifice of prescribed dimensions with a certain head was agreed upon, and the flow through the opening divided by the area of the opening, expressed in inches, gave what is called a "miner's inch." So long as rough approximations were sufficient, this device served the purpose; but, as the demand is an increasing one while the source of supply is practically constant, the time will come, and indeed it has come in many localities, when a more accurate measuring device will be needed in order to insure a fair and economical distribution of our water. Section 1,262 of the Compiled Statutes of Montana reads:

"The measurement of water appropriated under this chapter shall be conducted in the following manner: A box or flume shall be constructed with a head-gate placed so as to leave an opening of six inches between the bottom of the box or flume and lower edge of the head-gate, with a slide to enter at one side of and of sufficient width to close the opening left by the head-gate, by means of which the dimensions of the opening are to be adjusted. The box or flume shall be placed level, and so arranged that the stream in passing through the aperture is not obstructed by back water, or an eddy below the gate; but before entering the opening to be measured the stream shall be brought to an eddy, and shall stand three inches on the head-gate and above the opening. The number of square inches contained in the opening shall be the measure of inches of water."

As has already been pointed out in your meeting of December, 1893, this section is unsatisfactory.

We do not understand exactly what is meant here by the term "eddy," as no definition of that word will fit in the sentence and make sense. If it is intended, as many suppose, that the water shall be brought to a standstill before passing through the orifice, we have an impossible condition. The water is to "stand three inches on the head-gate and above the opening;" this is ambiguous. An engineer would naturally conclude that the measurement was to be taken, as is cus-

tomary, at a distance of several feet up the stream from the opening, but I have been assured by a lawyer that it should be measured directly above the opening; although just how this measurement can be accurately taken is not apparent. Our experiments show that on an opening about forty-two inches long the depression of the surface of the water directly over the opening would approximate one-half inch more or less. This was determined by placing a straight edge on the surface of the water at that point. If the lowest point of this depression measured three inches in height over the top of the opening, the actual head would then be about three and one-half inches instead of three inches, giving the owner of 250 inches something like ten per cent. the advantage over the owner of say 50 or 100 inches.

Nothing is said regarding the thickness of the plank enclosing the opening. Our observations lead us to believe that up to two inches, at least, the escaping jet touches only the inner edge on three sides. On the upper side the stream is in contact with the entire thickness of the plank, but I doubt whether any perceptible error is introduced on this account. If the plank is made sufficiently thick to suppress the contraction of the escaping jet, we may look for an increased discharge. The same increase may be obtained by prolonging the edges with boards so that the length of the box so formed shall be say two or three times its least dimension.

The law does not specifically prohibit the use of curved entrance to the orifice, and this we know would increase the flow to a very marked extent. If the ends of the opening coincide with the sides of the box, we get a partial suppression of the contraction of the escaping jet and consequently an increased flow. Lack of time prevented us from showing by experiment exactly what this would amount to, but past experiments on weirs show that this suppression is a very important factor in increasing the discharge. In the case of a weir two feet long with a head of six inches the increase would be about five per cent. Where conoidal mouthpieces have been used, Francis (Lowell Experiments) obtained a coefficient of 0.94 with a head of 1.52 feet; Unwin (*Philosophical Magazine*, October, 1878), with heads of from 0.98 foot to 1.4 feet, obtained coefficients as high as 0.991, almost the theoretical flow, an increase of about sixty-six per cent. over the ordinary rectangular opening; Castel (*Annales des Mines*, 1836), with heads of from 0.75 foot to 1 foot, obtained a coefficient of 0.956. These examples are mentioned merely to show the possibilities which attend the alteration of the conditions under which the discharge takes place, and to impress the necessity of defining exactly what conditions shall be adhered to when appropriated water is to be measured.

Although many experiments on the flow of water through orifices,

notably those by Lesbros, Hamilton Smith, Jr., Ellis, Francis, Unwin, Steckel, Bazin and Castel, are on record, the majority were made with circular orifices, and none of them are suitable for obtaining close results under the conditions prescribed by our Montana law. My experiments were made with the object of determining the amount of water in cubic feet per second represented by a miner's inch, measured according to the Montana statute, through openings of various widths, without supression of end contractions, and to deduce a series of coefficients for rectangular orifices 0.5 foot high and of variable width, with a head of 0.5 foot over

FIG. 1. PLAN SHOWING ARRANGEMENT OF APPARATUS.
Scale, 1 inch = 12 feet, or $\frac{1}{144}$.

the center. The coefficients so deduced are to be used in the formula $Q = c\ a\ (2gh)^{\frac{1}{2}}$. The experiments were intended to cover a range of from 36 to 252 miner's inches, the available water supply not allowing of larger measurements. Owing to formation of waves in the approaching water, when the opening exceeded six inches wide by thirty inches long, all measurements made on larger openings than this were rejected as being unreliable. It is to be regretted that owing to the shortness of the time during which the water could be obtained, this difficulty could not be remedied. After passing through the orifice, the water was measured by passing it over a weir two feet long. The soil in the channel

between the orifice and the weir consists largely of clay, and, after being soaked with water for several days, admits of practically no percolation. This was demonstrated by allowing the water to stand in the channel above the orifice.

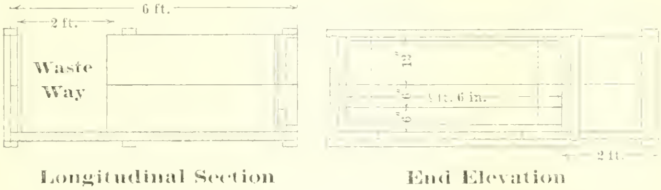


FIG. 2. MINER'S INCH ORIFICE.
Scale, 1 inch = 4 feet, or $\frac{1}{48}$.

There was a slight leakage in the box enclosing the weir; but, as it appeared on the side where the hook gauges were located, there was no difficulty in measuring it approximately with a small weir. The leakage varied from 0.0031 to 0.0087 cubic foot per second, according to the depth on the weir, and was added to the flow over the weir. No difficulty was experienced in obtaining smooth water, free from eddies, in the weir box. The heads were measured with a hook gauge reading

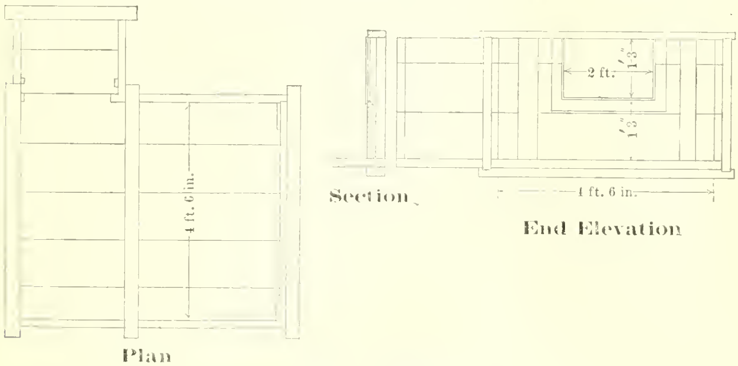


FIG. 3. WEIR.
Scale, 1 inch = 4 feet, or $\frac{1}{48}$.

to 0.001 of a foot and taken at points six feet back of the openings. The weir box was built with a space two feet square on the side; this space is to be used in the future for holding a float for a Carpenter Register, and is separated from the main box by planking carried to within one inch of the bottom. The head was taken from the orifice box through a hole one inch in diameter bored perpendicular to the side, about six feet back of the orifice, near the bottom, and communicating with the hook gauge through a galvanized iron pipe three quarters of an inch in diameter.

An attempt was made to imitate as far as possible the usual practice in the construction and use of a miner's inch measuring device. The openings for the orifice measurements were made by placing vertically planks one inch thick and of various widths, so that the pressure of the water would hold them against the end of the box. The end of the box was made by placing two planks, two inches thick, horizontally, with a space of six inches between them (as shown in Fig. 2). Owing to a slight settlement of the weir box when it contained water, levels were taken from the crest to the hook with almost every reading.

The practice of taking several readings within a stated time and reducing them to a mean head, was not followed here; but we allowed the water to rise very slowly on the orifice hook, regulating the rise by the waste gate Fig. 1. Another waste gate farther up the stream regulated the flow approximately.

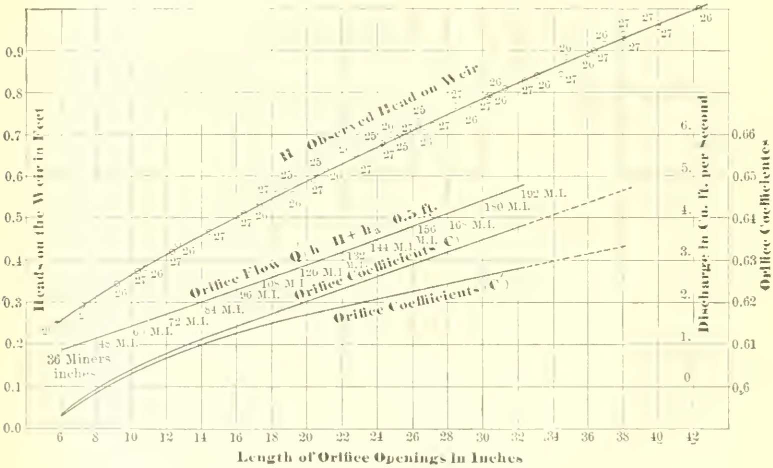


FIG. 4. DIAGRAM OF RESULTS.

$$\left.\begin{aligned} Q &= C \times 0.5 \times l \sqrt{2gH}. \\ Q' &= C' \times 0.5 \times l \sqrt{2g\,(H + h_a)}. \end{aligned}\right\} \text{Discharge in cubic feet per second.}$$

$\sqrt{2g} = 8.02.$

$T = 40°$ to $50°$ Fahr.

$H =$ observed head.

$h_a =$ head due to velocity of approach.

$C =$ coefficient.

$C' =$ coefficient corrected for velocity of approach.

$l =$ length.

The numbers shown on the upper curve refer to the dates on which the experiments were made.

The observed weir heads for different lengths of orifices are plotted in Fig. 4, and a curve is drawn through these observed heads.

All calculations for flow are based on this curve, which is subsequently corrected for leakage and for velocity of approach. The correction for velocity of approach was made as follows: $h = H + 1.4\ V_a^2 \div 2\ g$, in which $H =$ observed head, $V_a =$ velocity of approach and $g =$ acceleration of gravity. Smith's formula, $Q = c\ \frac{2}{3}\ l\ (2\ g\ h)^{\frac{1}{2}}\ h$, was used, h being the observed head H plus the head h_a causing the velocity of approach.

Smith's curve of coefficients for a weir two feet long, with contractions, was drawn from data principally supplied by Fteley and Stearn's experiments with a weir three feet long, with heads from 0.6 foot to 0.95 foot; Francis' experiments with a weir four feet long with heads from 0.7 foot to 1 foot; Smith's experiments on weir two feet and six inches long with heads from 0.6 foot to 1.7 feet; and Lesbros' experiments on a weir 1.97 feet long with heads from 0.4 foot to 1.4 feet. These experiments give insufficient data for a very precise location of the coefficient curve for weirs two feet long with heads of from 0.1 foot to 0.5 foot, and the writer believes that the results given are a little high, possibly averaging one-half per cent., as in deducing a curve of orifice coefficients a lack of uniformity was observed between those places, the results being higher than would be expected, assuming the remainder of the deduced curve, which was fairly uniform, to be correct. Francis' formula between these heads, on the contrary, gave results somewhat lower than one would expect; but Francis' experiments were made on longer weirs, and it is not claimed that his formula holds good for short weirs, especially where the head is greater than one quarter the length of the weir. Cippoletti claims that Francis' formula gives results about one per cent. too low.

The coefficient curve for the orifices as drawn by the writer therefore lies between the points indicated by the use of Smith's formula with his weir coefficients, and Francis' formula for measured heads of 0.5 foot and under, while it coincides with the points indicated by Smith's formula, where the measured heads were above 0.5 foot. To insure perfect contraction, according to Smith, the distance from the ends of the weir to the sides of the box should be at least $3h$, while a distance of $2h$ might introduce an error of one-half per cent. This latter condition is fulfilled in measuring water coming from orifices up to twenty-two inches in length. The distance from the crest of the weir to the bottom of the box was 1.24 feet. The weir edges were made of two inch by one-sixteenth iron screwed to the woodwork, which consisted of two-inch plank firmly braced. The temperature of the water was between 40°F. and 50°F. during the experiments; and $(2g)^{\frac{1}{2}}$, corrected for altitude and latitude, was taken at 8.02.

Fig. 4 shows the curve of observed heads; a curve of orifice coeffi-

cients without allowance for the head producing the velocity of approach; a curve of orifice coefficients deduced for a head: $(H + h_a) = 0.5$ foot, and a curve indicating the total discharge in cubic feet per second from the orifices, with the corrected coefficients. It will be seen that, unless the velocity of approach is considered in the case of an orifice 6 inches wide and 30 inches long, under the conditions assumed, an increased flow of 1.46 per cent. is obtained; this amount decreases as the area of the orifice decreases in proportion to the area of cross-section of the approaching channel.

Mr. Hamilton Smith, Jr., made three experiments to determine the value of a California miner's inch. The plank used was 3 inches thick, and was beveled to 1 inch at the orifice. The contraction touched only the inside edge and the corners. The results of his experiments are given below.

Eureka Lake Standard Orifice, 50 inches long, 2 inches wide, 6 inches head above top of opening. Full contraction. Temperature of water about 65°. $(2g)^{\frac{1}{2}} = 8.018$. Size of opening: length, 4.1667 feet; width, 0.16667 foot. Head, 0.5833 foot. Discharge in cubic feet per second, 2.618. C 0.6156, c 0.6161.

Mr. Smith also made experiments with the North Bloomfield Standard called 200 miner's inches. $12\frac{3}{4}$ inches long, 6 inches head above the top of the opening, 12 inches wide, plank 0.12 foot thick, temperature about 50°, with the following results:

Length. l	Width. w	Head. $H = h$	Discharge, cu. ft. per sec.	C	c
1.0625	1	1	5.045	0.5922	0.5988

The coefficients C and c are used in the following formulas respectively: $Q = C\,(2gh)^{\frac{1}{2}}\,l\,w$ and $Q = c\,\frac{2}{3}\,l\,(2\,g)^{\frac{1}{2}}\,(H_b^{\frac{3}{2}} - H_t^{\frac{3}{2}})$. $H_b = h + w \div 2$ and $H_t = h - w \div 2$.

Following is given a table of the results obtained from the writer's experiments made at Bozeman, October, 1894:

Determination of Value of Montana Statute Miner's Inch.

Thickness of Plank at the Opening, 2 Inches.

$(2g)^{\frac{1}{2}} = 8.02$. Temperature of water 40°–50° F. $Q = C(2gh)^{\frac{1}{2}} lw$, $h = H + h_a = 0.5$ foot.

Length in in.	Width in ft. w	Number of Miner's ins.	Discharge in cubic feet per second. Q	C	Gallons per Miner's inch in 24 hours.	Percentage of increased flow per unit of area.	Head over center in feet. $h = H + h_a$
6	½	36	0.8406	.593	15108		
8	½	48	1.13214	.599	15260	1.008	.5
10	½	60	1.4246	.603	15363	1.677	.5
12	½	72	1.72088	.607	15464	2.355	.5
14	½	84	2.0176	.61	15542	2.855	.5
16	½	96	2.31719	.613	15620	3.372	.5
18	½	108	2.6174	.6155	15681	3.79	.5
20	½	120	2.9168	.6173	15727	4.097	.5
22	½	132	3.2173	.619	15770	4.3825	.5
24	½	144	3.52115	.621	15823	4.7347	.5
26	½	156	3.8268	.623	15872	5.057	.5
28	½	168	4.1318	.6246	15913	5.317	.5
30	½	180	4.4404	.6265	15964	5.639	.5

The hook gauge indicated a head (H) = 0.5 foot in the orifice box when the readings on the weir gauge were taken, but the actual head in the orifice box was H + the head due to velocity of approach, taken as $h_a = 1.4\ V^2 \div 2g$. The value of C was deduced for a head, $h = H + h_a$; this value of C was then inserted in the formula $Q = C\ (2gh)^{\frac{1}{2}}\ l\ w$ when $h = 0.5$ foot and a value for Q found, which is the value given in the table.

CONCLUSIONS.

The statute apparently assumes that a person appropriating 180 miner's inches gets five times as much water as a person appropriating 36 miner's inches. As might be expected, our experiments show that this is not a true ratio. As a matter of fact, as will be seen from the table, the former gets about 5.64 per cent. more water per unit of area of orifice than the latter.

Your committee believes that fairer and more satisfactory results would follow if the standard of measurement were expressed in cubic feet per second *without reference to the method of measurement.* The probable result of this would be that weirs would rapidly displace all other devices where accuracy was desired.

The enclosed form of Act is submitted for the approved of the Society, and we recommend that the Legislature be asked to adopt it.

We have many experiments on the flow of water over weirs, and there is no trouble in obtaining results that can be relied upon as being correct within one per cent. The weir has a further advantage over orifices in effecting a saving of head in diverting water for measuring purposes. This, in some cases, is a matter of considerable importance.

Permanent records of fluctuating heads may be kept by using an automatic registering device of the Carpenter pattern. This I believe to be an important matter. If canal companies and joint owners would use weirs with recording registers, I believe that much of the prevailing friction between neighbors would be done away with. These registers can be purchased in Denver for about $20.

In selecting a value to represent a miner's inch of water, your committee would suggest that, providing the law giving present appropriators a water-right expressed in miner's inches be repealed, if 2.5 cubic feet per second were considered an equivalent for 100 miner's inches, 5 cubic feet per second an equivalent for 200 miner's inches and so on, no injustice would be done anyone. We would then be able to do what is now almost impossible; namely, to collect fairly reliable data relating to the duty of water used for irrigation. As matters stand at present we are told by certain parties that they use so many inches of water so many times per season, in order to irrigate a given area of land. Ordinarily we do not know how much water that represents, and we have no means of finding out. If a weir with a registering device were used, a glance at the card would tell the whole story. It would also show whether the appropriator was getting more or less than his share.

The Experiment Stations would gladly furnish cards showing the flow over weirs for different depths. In fact, Prof. L. G. Carpenter, of the Colorado Station, at Fort Collins, has already done so, both for rectangular weirs and for the Cippoletti weir.

The latter weir has sides which are inclined from the vertical $\frac{1}{4}$ in 1. This form of weir was designed for the Villoresi Canal, projected in 1881 by the Province of Milan, Italy, by Cesar Cippoletti.

Cippoletti attempted to perfect a design for a weir which would measure the discharge with an error not to exceed $\frac{1}{2}$ per cent. and at the same time to retain the simple formula $Q = Clh\,(h)^{\frac{1}{2}}$. The value of C he determined to be a constant $= 3.3\frac{2}{3}$. Cippoletti's weir has been in use for about ten years in Italy, and has given general satisfaction.

Messrs. Flinn and Dyer have published the results of their experiments on the Cippoletti weir in the *Transactions of the American Society of Civil Engineers*, July, 1894. These experimenters conclude that a properly constructed Cippoletti weir will give results correct within one

per cent. We believe that no better form of weir can be selected by irrigators. For the measurement of large bodies of water where the construction of a weir is impracticable, straight measuring flumes similar to those used by Mr. Mead, State Engineer for Wyoming, and Mr. Clemens Herschel's venturi meter, are suitable.

AN ACT

establishing a standard of measurement for water, defining the equivalent of a miner's inch and repealing Section 1262, Division 5, of the Compiled Statutes of the State of Montana and all conflicting laws.

Be it enacted by the Legislative Assembly of the State of Montana:

SEC. 1. Hereafter a cubic foot (7.48 gallons) of water per second of time shall be the legal standard for the measurement of water in this state.

SEC. 2. Where water-rights expressed in miner's inches have been granted, one hundred miner's inches shall be considered equivalent to a flow of two and one-half cubic feet (18.7 gallons) per second; two hundred miner's inches shall be considered equivalent to a flow of five cubic feet (37.4 gallons) per second, and this proportion shall be observed in determining the equivalent flow represented by any number of miner's inches.

SEC. 3. Section 1262, Division 5, of the Compiled Statutes of the State of Montana, and any laws in conflict with this Act are hereby repealed.

THE CONTRIBUTION BOX.

Members of the associated societies, and other persons, are invited to send to the Secretary, for this department of the JOURNAL, such matters of general interest as may come to their notice.

Welcome!

In the JOURNAL for December, 1894, the Box had the pleasure of announcing the decision of the Western Society of Engineers to continue its membership in the Association of Engineering Societies.

With equal pleasure we now turn to welcome two societies just admitted to membership, the Denver Society of Civil Engineers and the Association of Engineers of Virginia, numbering respectively twenty-five and thirty-seven members.

Each society added to our roll increases the value of the JOURNAL, not only to the members of the societies participating, but to the profession at large, and thus tends to increase its circulation and importance.

The Box entertains no doubt that the co-operation of the societies in question will redound to their advantage as well as to that of the Association.

Our Societies and the Legislators.

In *The Library* for the current month we have referred to the work of our new member, the Association of Engineers of Virginia, in shaping legislation by securing the passage of a new building law by the city of Roanoke, Va., in accordance with a draft submitted by the Association.

As will be seen by the proceedings of the January meeting of the Association, printed in this number, that body has also interested itself in the matter of a law looking to the improvement of the roads of the State.

The Montana Society has similarly brought its pressure to bear upon the legislature of that State in behalf of laws respecting the regulation of water measurement, the duties and compensations of county surveyors, and the improvement of roads. Professor Ryon's report upon the measurement of water, with a copy of the proposed act, is printed in the present number, and under the proceedings of the society is given an account of its efforts in the other two directions named.

As we go to press we learn that the Legislature, which, it is significantly remarked, was "elected to elect United States Senators" has indefinitely postponed the consideration of all three of the bills submitted. The society, however, nothing daunted by this frosty reception of its efforts for the public good, proposes to keep up "a fight all along the line for the next three years."

The Federated Institution of Mining Engineers.

Co-operation among engineering societies is not confined to this side of the water. The institution whose name appears at the head of this article comprises now six

important societies having their headquarters mostly in the north of England and in Scotland. Founded in 1889, it began operations, like our own Association, with but four societies, but these four boasted a combined membership of about 1200. The six societies now federated show a total membership of over 2000.

The scheme of federation is in many respects quite different from that of our own Association. The several societies publish separately their own transactions, and the work of the institution is not confined, as in our case, to the publication of papers, but extends also to the holding of general meetings.

Mr. M. Walton Brown, secretary of the North of England Institute of Mining and Mechanical Engineers, with headquarters at Newcastle-upon-Tyne, is secretary also of the Federated Institution, and to him we are indebted for interesting information respecting its scope and work, as well as for a copy of a report upon Flameless Explosives by a committee of the North of England Institute. This report, of sixty-nine pages and one lithograph plate, is the result of an elaborate series of experiments with various explosives and appliances connected with shot-firing, made as nearly as possible under the conditions obtaining in a mine.

The experimental station is at Hebburn-upon-Tyne, and is supplied with natural gas derived from a blower in the workings of the Hebburn colliery, about 500 yards distant.

The labors of the committee resulted not only in the report before us, but in a formidable array of papers upon various subjects more or less intimately connected with the investigation, contributed by members of the committee and published in the Transactions of the Federated Institution of Mining Engineers.

Annual Report of the Chairman.

The attention of our readers is called to the Annual Report of the Chairman of the Board of Managers of the Association, printed, under the Proceedings, in this number of the JOURNAL.

The Chairman's review of the history of the Association will be of interest to all, and especially to the members of the newly admitted societies.

The report of progress for the year just past shows a very considerable increase in the volume of the JOURNAL, with corresponding increase in the receipts and expenditures.

Under Prospects for the Future, the Chairman discusses projects recently renewed, looking to the establishment of a more intimate union between the societies of the Association, projects which we shall hope to see more fully discussed in this department.

The Articles of Association.

In this number is presented also a copy of the Articles of Association, which constitute our fundamental law.

From time to time, amendments to these articles have been submitted to the societies by the Board of Managers, but these have uniformly failed of the necessary ratification, and the articles therefore remain to-day as they were adopted at the first meeting of representatives of the four original societies, held in Chicago, December 4, 1880.

Trolley English.

In the Contribution Box for February, 1894, under the heading, "As She is Printed," we gave the following, taken from the transfer ticket of a Philadelphia street-car line :

"This Transfer Ticket is given only to persons entering car on Pine Street, and asks for and receives same at time of payment of Cash Fare. Otherwise the Conductor is not permitted to give it."

A pocket-guide to the trolley and other street-cars of the same city, recently issued, contains the following caution :

"Owing to the starting of new lines, and change of schedules, the information below is as near correct as possible."

THE LIBRARY.

It is proposed to notice briefly, in this department of the JOURNAL, such engineering publications as may find their way to our shelves.

Publishers are requested, in sending works for review, to state the prices of same.

The Engineer and Contractor. Mr. Ernest McCullough, C. E., Member of the Technical Society of the Pacific Coast, whose treatise on Public Works we briefly noticed in the LIBRARY for December, appears as the managing editor of this new engineering weekly, whose first number appeared January 4, 1895.

It is an eight-page sheet devoted primarily to the interests of western engineers, and one of its principal aims is to present, for the benefit of engineering contractors, the latest information respecting construction work in that section. An illustrated paper on the diverting dam of the Peoria Canal Co., by Mr. H. Clay Kellogg, Member Tech. Soc. Pac. Coast, begins with the first number and runs into the fourth, where it is announced that "the next number will give a general idea of the manner in which the work is prosecuted, and some statement of cost." No. 5, however, brings the sad intelligence of the failure of this dam, with severe editorial strictures upon the manner in which the work was done, and particularly upon the policy of the management in dispensing with the services of the engineers before the dam was quite completed.

Mr. C. E. Grunsky, C. E., contributes a paper on Public Works in American Cities, read before the Political Science Club of the University of California, and Mr. Otto von Geldern, Secretary Tech. Soc. Pac. Coast, one on Macadamized Roadways.

It is to be hoped that the promise of this new journal that "in tone it will be quiet," will not be carried out too literally.

City Roads and Pavements suited to Oswego, New York. By William Pierson Judson, M. Am. Soc. C. E., M. Inst. C. E. Oswego, N. Y.: R. J. Oliphant, 1894. 60 pages.

While this work, as indicated in its title, is prepared with special reference to the needs of the city of Oswego, it is believed that it will find application in many other cities of this country.

Chapter I is devoted to the local conditions obtaining in Oswego; Chapter II to a brief discussion of the claims of different systems of paving; and Chapter III–VIII to a more detailed consideration of their several advantages and disadvantages.

The author reaches the conclusion that sheet asphalt, laid upon the old stone pavements as a foundation, is best suited for the main business streets of heaviest traffic; block sandstone upon a 6-inch concrete base, for the main business streets with grades steeper than 3 per cent.; vitrified brick upon a 6-inch base for semi-business streets and thoroughfares, and sheet asphalt for resident streets where there is much driving.

The work is very handsomely got up and is profusely illustrated with photographs and with colored lithographs of the different forms of construction. The inadvisability of using broken cobblestones for foundation is well illustrated in one of the latter.

City of Portland, Maine. Annual report of the City Engineer for the year 1893-1894. By Mr. George N. Fernald, City Engineer.

The extent to which the question of sanitation is engrossing the minds of the dwellers in cities is indicated by the fact that by far the larger part of this report is taken up with the discussion of matters pertaining to sewerage. Nearly a mile of sewers was constructed during the year covered by the report, and the city now has a total of more than 40 miles.

Theoretical Mechanics. An Elementary Treatise on —. By Alexander Ziwet, Assistant Professor of Mathematics in the University of Mich. igan. Part III: Kinetics; 236 pages; 5½ x 9 inches. New York: McMillan & Co., and London, 1894. Price, $2.25.

This is the third volume of the series, of which the first two parts, on Kinematics and on Statics, respectivly, were noted in the September Journal, and is altogether in keeping with them. The larger portion of the present volume is taken up by Chapters V and VI, treating respectively of the kinetics of a particle and the kinetics of a rigid body. The motion of a variable system is briefly treated in Chapter VII.

Genessee River Storage Project. Final Report on —. By George W. Rafter, Engineer in Charge. Albany, 1894.

The prominent feature of this report is the account of tests of 174 12-inch concrete cubes, made chiefly with a view to determining the effect of the character of the stone and sand used in the concrete and the availability of American cements. The results are contained in an elaborate table, giving the final compressive stress, and that at which the first crack appeared, and in most cases the observed compression of the block.

From the results of his tests the author concludes that the strongest concretes are secured when the volume of the mortar is very little, if any, in excess of the voids, as measured before compacting, or even a little less.

The tests were made upon the great testing machine of the Phœnix Bridge Works, at Phœnixville, Pa.

Sewage Disposal. A Discussion of the Prevailing Rules and Practices relating to —. By Wynkoop Kiersted, C.E., M. A. S. C. E. New York: John Wiley & Sons. 1894. 182 pages, 5 x 7 inches. Price $1.25.

The extent to which the subject of sewage disposal is interesting the public mind may be gathered from the appearance, in rapid succession, of treatises upon the subject. In the Journal for November, we noticed the works of Messrs. Waring and Rafter. We now have before us this little book by Mr. Kiersted, member of the Engineers' Club of Kansas City, whose paper upon Water Supplies appeared in the Journal for January last.

Mr. Kiersted advocates what may be called the natural or vital purification of sewage, namely, that by dilution or by discharge into running streams, holding that if this is properly regulated as to amount and character, and if the water is afterward properly treated by filtration, no injury need be wrought thereby.

This method is therefore given the place of honor in the work, but the methods by irrigation, by intermittent filtration, and by chemical precipitation, are also discussed.

Curiously enough, the work is printed in short forms upon long pages, giving what appears to be an unnecessarily deep margin at the foot of each page.

Massachusetts State Board of Health. TWENTY-FIFTH ANNUAL REPORT OF ——, FOR 1893. Boston, 1894.

The excellent work of this Board has made it world-famous, and its reports are looked upon as among the most valuable of contributions to the literature of sanitation. In addition to the matter usually treated of, the present report contains papers upon the amount and character of organic matter in soils, and its bearing upon the storage of water in reservoirs, by Thomas M. Drown, M.D., chemist of the Board; Experiments upon the Purification of Sewage and Water at the Lawrence Experiment Station during 1893, by George W. Fuller, Biologist in charge (143 pages); the Chemical Precipitation of Sewage at the World's Columbian Exposition, Chicago, 1893, by Allen Hazen, Chemist, Department of Water Supplies, Sewage and Fire Protection; and Isolation Hospitals for Infectious Diseases, by S. W. Abbott, M.D., Secretary of the Board. The last-named paper is illustrated by plans of the hospitals at Cambridge, Ealing, and London, England, Blegdam's Hospital, Copenhagen, and with designs for a small isolation hospital.

Mr. Ira F. Mills describes the filter-bed installed during the present year at Lawrence, Mass, as the result of the work of the Board in connection with the investigations made at its experiment station there. The bed, finished in September, 1893, covers an area of 2½ acres, supplies water for about 47,000 persons, and cost about $67,000. Very frequent examinations of the water show that 98 per cent. of all the bacteria in the river-water applied to the filter are removed directly by it, and that only one-half of 1 per cent, and those of varieties not known to be in any way injurious to health, finally reach the persons using the water. For the three months of October, November and December, the average deaths from typhoid fever in Lawrence, during the five years preceding 1893, averaged eighteen, while, in 1893, or after the introduction of the filter, only four deaths occurred from that disease during the same three months.

Concrete Bridge over the Danube at Munderkingen. (Betonbrücke über die Donau bei Munderkingen.) Stuttgart, 1894.

This arch, with 164 feet (50 meters) span and 16.4 feet (5 meters) rise, spanning the Danube with one opening, is of concrete composed of one part Portland cement from the Ehingen-Blaubeuren works in Upper Swabia, two and one-half parts river sand and five parts river gravel, both of the latter from the Danube.

In order to render the structure statically determinate, and also to prevent injurious stresses under changes of temperature, the arch is jointed at the crown and at the springs. As the bridge is on a skew of 15 degrees, the twelve boxes constituting each joint are set one in advance of the next, across the width of the arch. After the completion of the arches, the joint-boxes were loosely filled with cement mortar, to prevent them from rusting. This, it is claimed, does not interfere with the distribution of the stresses.

On the left side of the arch the intrados is struck with a radius of 213 feet (65 meters); but that on the right is struck with a radius of 230 feet (70 meters) for two-thirds of the distance from the crown to the skewback, and with a radius of 151 feet (46 meters) for the rest of the distance.

The cross-section of the arch rib sustains a maximum pressure of about thirty-four tons per square foot.

The total average settlement of the crown was about 4¾ inches (116 mm.).

The Great Arched Bridges of the Royal State Railway Stanislau-Woronienka. (Die Bauvollendung der grossen gewölbten Brücken der k. k. Staatsbahn Stanislau-Woronienka.) By Ludwig Huss, Vienna. 1894. Pamphlet, 8 pages. Reprint from Zeitschrift des Oesterr. Ingenieur- und Architekten-Vereins, Nr. 46. 1894.

Of the two arches here mentioned, both of which span the River Pruth, in Galicia, that at Jaremcze has a span of 65 meters, or 213 feet, and is believed to exceed, in this respect, any other stone railway bridge in the world. The first train passed over these bridges October 26, 1894, and on the 11th of the following month they were tested with a load of three locomotives, which produced no deflection. The pamphlet is illustrated with photographic views of the bridges.

An Ordinance to Provide Regulations Covering the Erection of Buildings in the City of Roanoke, Va. Compiled by the Engineers' Association of Virginia. Approved June 23, 1894. Roanoke, Va. 1894. Pamphlet, 20 pages.

This pamphlet is a gratifying evidence of the esteem in which the advice of the Association in question is held by the municipalities of its State, and we trust it may be taken also as indicating a growing disposition on the part of our legislators to look to such organizations for advice in matters pertaining to their several spheres.

The ordinance provides that plans, specifications and statements of material shall be submitted to the City Engineer before construction is begun, and it is made the duty of that official to examine the condition of all buildings undergoing alterations or being erected within the city limits, and to serve notice upon contractors or builders, and upon owners or architects, of structures which he may deem unsafe.

The report wisely devotes a page or two to definitions of the terms employed. Diagrams are given showing prescribed thicknesses of walls, arrangements of plumbing and drainage, etc.

Le Canadian Pacific Railway. By MM. L. Périssé & A. V. Roy. Paris 10 Cité Rougement. 1894. Reprint from Mémoires de la Société des Ingénieurs Civils de France.

The authors here give the result of a very careful study of the system under consideration, made during their visit to this country in 1893. The location, construction and operation of the road are described in considerable detail, and the paper is illustrated by two plates showing the plan and profile of the line, with illustrations of bridges and other structures, and of rolling stock.

Spannungs-Ermittelung und Stellung der Trägerquerschnitte für Biegungsmomente, welche nach Grösse und Richtung veränderlich sind. (Determination of the Stresses and Cross-Section of Beams subject to Bending Moments Varying in Amount and in Direction.) By Professor G. Barkhausen, of Hanover.—Reprint from *Centralblatt der Bauverwaltung.*

The author, finding the methods in use for the purpose here indicated more or less deficient in certain respects, proposes here a method which, he claims, requires no special preparation upon the part of the reader, which, under all cirsumstances, permits an exact solution of the problem in hand, and which facilitates a general view of the relations obtaining in the given case.

The process consists in drawing, in the cross-section for the danger points, lines

representing the stresses which would obtain if a bending moment = 1 gradually described an angle of 360° with reference to the cross-section.

The method is illustrated by two examples showing its application to purlins of double channel section and Z section respectively.

Masonry Dams, The Design of — (Berechnung der Staumauern). Von Franz Kreuter, ord. Professor der Ingenieurwissenschaften an der Königl. Bayerischen Technischen Hochschule in München. Berlin: 1894. Wilhelm Ernst & Sohn. Pamphlet, 12 pages.

The author here elaborates his method for the design of masonry dams, as somewhat more briefly outlined in his paper published in the Proceedings of the Institution of Civil Engineers, Vol. CXV. The right-angled triangle with vertical back is taken as the simplest among those cross-sections which give uniform stability throughout, and the method consists in finding the necessary modifications for transforming this ideal section into one adapted to the conditions of practice.

The cross-section is divided horizontally into four parts, the uppermost of which is rectangular. The width of this portion is supposed to be determined by local conditions, and its height is made equal to the product of the width by the square root of the specific gravity of the masonry.

The portion next below is trapezoidal, with height equal to that of the top portion, and bottom width 1.7 times its top width, the latter being of course the same as the uniform width of the top portion.

The two remaining parts have curved profiles, and their equations are much less simple.

Society Proceedings.

Engineers' Society of Western Pennsylvania. Proceedings of ——. November, 1894. Vol. X, No. 9.

This number contains a paper of ten pages, by Mr. Daniel Ashworth, on Losses in Boiler Practice and Some of their Causes. The author claims that the losses in question are due less frequently to insufficient theoretical knowledge than to neglect of the obvious requirements of good, every-day practice in the boiler-room itself, a neglect evidenced by such defects as cracked furnace-walls, the fouling of tubes, the accumulation of scale, etc.

December, 1894. Vol. X, No. 10.

Wr. William A. Bole discusses Losses in the Steam Engine, arguing that about five-sixths of the heat required in producing steam are wasted in the exhaust. In the Proceedings of the Chemical Section, Mr. Francis C. Phillips describes Some Uses of Hydrogen Peroxide in Analytical Chemistry.

January, 1895. Vol. XI, No. 1.

This number comes to hand, not "as we go to press" but as we are nearly coming off. It contains the proceedings of the 15th annual meeting, held in Allegheny, Pa., January 17, 1895. President Davis, in his annual address, confines himself chiefly to the engineering interests of Pittsburg and its vicinity.

The Treasurer's report for the year ending January 17, 1895, shows an expenditure, for "printing and binding," of $1,388.50. The total number of pages in the volume for the year, including papers, advertisements, blanks, cover, etc., was 352, making the cost, for a membership of about 450, $3.94 per page.

Assuming that these figures include composition, corrections, paper, presswork, illustrations and binding, we find that, for the same items, the cost of the Journal

of the Association of Engineering Societies, with an average aggregate membership, during 1894, of about 1200, was but $3.26 per page, or more than one-sixth less, notwithstanding that our pages, of the form used for papers, etc., contain more than one-third more matter, to say nothing of a large number of small-type pages in the Journal containing, of course, a quantity of matter much greater still and costing much more for composition.

The comparison merely illustrates the economy that may be effected by co-operation in this as in other matters.

Engineers' Club of Philadelphia, January, 1895. Vol. XI, No. 5.

Dr. Henry Leffmann discusses the timely subject of the Filtration of Public Water Supplies; and Mr. George A. Bullock, Chief of the City Bureau of Highways, describes recent progress in Philadelphia in the matter of highway improvement. Mr. Frederick H. Lewis contributes a set of Specifications for Portland Cements and Cement Mortars, with a valuable paper discussing them; and Mr. John L. Gill, Jr., maker of the Gill safety tubular boiler, describes and illustrates the remarkable and disastrous explosion of a battery of thirty-six plain cylinder boilers at Shamokin, Pa., on October 11, 1894. Following the practice of the *Proceedings*, the pages and the photographic views of the wreck are headed with the legend "Gill—Boiler Explosions," giving the uninitiated the impression that the paper and the photographs refer to an explosion of Gill boilers, which, it is needless to say, was quite foreign to Mr. Gill's intention.

In the proceedings of the meeting of November 17th is reported the discussion upon the invitation extended to the Club to confer with this Association with a view to membership therein, a discussion which unfortunately resulted in the Club's declining the invitation.

Journal of the New England Water Works Association. Quarterly. December, 1894. Vol. IX, No. 2. 70 pages.

This number contains, among other valuable papers, Notes on European Water Supplies, by Mr. Allen Hazen, read before the Boston Society of Civil Engineers, and one by Mr. George Bowers, City Engineer of Lowell, describing experiments with tube wells in that city, and based upon a discussion of the subject before the same society.

Mr. Wm. Paul Gerhard, C. E., discusses the Water Service and Fire Protection of Theatres. Mr. George F. Chase describes the Laying of a 16-inch Main across a Rocky Mill Stream and over a Dam. Mr. J. C. Whitney contributes a paper on the Care of a Water Meter, and Mr. R. C. P. Coggeshall, Secretary of the Association, describes a Portable Platform to Aid in Excavating Trenches. The number closes with the Association's valuable table of statistics for the year 1893, in which are embraced twenty-one New England towns and the cities of Troy and Yonkers, N. Y.

ASSOCIATION OF ENGINEERING SOCIETIES.

Articles of Association.

The following Articles of Association were adopted at a meeting held in Chicago, December 4, 1880. At this meeting there were present representatives of the

Western Society of Engineers,
Civil Engineers' Club of Cleveland,
Engineers' Club of St. Louis;

and the

Boston Society of Civil Engineers

was represented by letter.

FOR THE PURPOSE OF SECURING THE BENEFITS OF CLOSER UNION AND THE ADVANCEMENT OF MUTUAL INTERESTS, THE ENGINEERING SOCIETIES AND CLUBS HEREUNTO SUBSCRIBING, HAVE AGREED TO THE FOLLOWING

ARTICLES OF ASSOCIATION.

ARTICLE I.

NAME AND OBJECT.

The name of this Association shall be "THE ASSOCIATION OF ENGINEERING SOCIETIES." Its primary object shall be to secure a joint publication of the papers and transactions of the participating societies.

ARTICLE II.

ORGANIZATION.

SECTION 1. The affairs of the Association shall be conducted by a Board of Managers under such rules and by-laws as they may determine, subject to the specific conditions of these articles. The Board shall consist of one representative from each society of one hundred members or less, with one additional representative for each additional one hundred members, or fraction thereof over fifty. The members of the Board shall be appointed as each society shall decide, and shall hold office until their successors are chosen.

SEC 2. The officers of the Board shall be a chairman and secretary, the latter of whom may or may not be himself a member of the Board.

ARTICLE III.

DUTIES OF OFFICERS.

SECTION 1. The Chairman, in addition to his ordinary duties, shall countersign all bills and vouchers before payment and present an annual report of the transac-

tions of the Board; which report, together with a synopsis of the other general transactions of the Board of interest to members, shall be published in the Journal of the Association.

SEC. 2. The Secretary shall be the active business agent of the Board and shall be appointed and removed at its pleasure. He shall receive a compensation for his services to be fixed from time to time by a two-thirds vote. He shall receive and take care of all manuscript copy and prepare it for the press, and attend to the forwarding of proof-sheets and the proper printing and mailing of the publications. He shall have power, with the approval of any one member of the Board, to return manuscript to the author for correction if in bad condition, illegible, or otherwise conspicuously deficient or unfit for publication. He shall certify to the correctness of all bills before transmitting them to the chairman for countersignature. He shall receive all fees and moneys paid to the Association and hold the same under such rules as the Board shall prescribe.

ARTICLE IV.

PUBLICATIONS.

SECTION 1. Each society shall decide for itself what papers and transactions of its own it desires to have published and shall forward the same to the Secretary.

SEC. 2. Each society shall notify the Secretary of the minimum number of copies of the joint publications which it desires to receive, and shall furnish a mailing-list for the same from time to time. Copies ordered by any society may be used as it shall see fit. Payments by each society shall in general be in proportion to the number of copies ordered, subject to such modification of the same as the Board of Managers may decide, by a two-thirds vote, to be more equitable. Assessments shall be quaterly in advance, or otherwise, as directed by the Board.

SEC. 3. The publications of the Association shall be open to public subscription and sale, and advertisements of an appropriate character shall be received, under regulations to be fixed by the Board.

SEC. 4. The Board shall have authority to print with the joint publications such abstracts and translations from scientific and professional journals and society transactions, as may be deemed of general interest and value.

ARTICLE V.

CONDITIONS OF PARTICIPATION.

SECTION 1. Any society of Engineers may become a member of this Association by a majority vote of the Board of Managers, upon payment to the Secretary of an entrance fee of fifty cents for each active member, and certifying that these Articles of Association have been duly accepted by it. Other technical organizations may be admitted by a two-thirds vote of the Board, and payment and subscription as above.

SEC. 2. Any society may withdraw from this Association at the end of any fiscal year by giving three months notice of such intention, and shall then be entitled to its fair proportion of any surplus in the treasury, or be responsible for its fair proportion of any deficit.

SEC. 3. Any society may, at the pleasure of the Board, be excluded from this Association, for non-payment of dues after thirty days notice from the Secretary that such payment is due.

ARTICLE VI.

AMENDMENTS.

These articles may be amended by a majority vote of the Board of Managers, and subsequent approval by two-thirds of the participating societies.

ARTICLE VII.

TIME OF GOING INTO EFFECT.

These articles shall go into effect whenever they shall have been ratified by three societies, and members of the Board of Managers appointed. The Board shall then proceed to organize, and the entrance fee of fifty cents per member shall then become payable.

These articles were adopted by the several societies upon the following dates:

Engineers' Club of St. Louis, January 5, 1881.
Civil Engineers' Club of Cleveland, January 8, 1881.
Boston Society of Civil Engineers, January 19, 1881.
Western Society of Engineers, April 5, 1881.

The Board of Managers was organized at Cleveland, January 11, 1881.

The following societies have since certified their acceptance of the Articles, and have become members of the Association of Engineering Societies:

Engineers' Club of Minneapolis, July, 1884.
Civil Engineers' Society of St. Paul, Minn., December, 1884.
Engineers' Club of Kansas City, January, 1887.
Montana Society of Civil Engineers, April, 1888.
Wisconsin Polytechnic Society, June, 1892.
Denver Society of Civil Engineers, January 24, 1895.
Association of Engineers of Virginia, February 1, 1895.

The Wisconsin Polytechnic Society withdrew from the Association in March, 1894.

Annual Report of the Chairman of the Board of Managers.

St. Louis, January 31, 1895.

To the Members of the Board of Managers of the Association of Engineering Societies.

Gentlemen:—In submitting to the Board of Managers, and to the members of the societies now belonging to the Association, my first annual report, I think it is desirable to present a short review of the history of the Association. More especially is this necessary since two new societies have recently joined the Association, and their members are unfamiliar with its past history.

I. Historical Review, to December, 1893.

The Association of Engineering Societies was first proposed about May, 1880, by the Civil Engineers' Club of Cleveland, Ohio, Mr. A. M. Wellington, a member

of that club, being the principal leader in the movement. After some correspondence with various local societies, committees were appointed by the Boston Society of Civil Engineers; the Western Society of Engineers, of Chicago; the Engineers' Club of St. Louis, and the Civil Engineers' Club of Cleveland; and the committees of the three societies last named met for the first time on December 4, 1880, in Chicago, for the purpose of preparing articles of association. There were present, at this meeting, Messrs. Benezette Williams and L. P. Morehouse from the Western Society; M. E. Ransom and A. M. Wellington of the Cleveland Club, and Professor Charles A. Smith of the St. Louis Club. The Boston committee was represented by letter only. Mr. John W. Weston, of the Western Society, was present by invitation. This committee prepared the present Articles of Association, which are reprinted in this number of the JOURNAL. These Articles were adopted by the Engineers' Club of St. Louis, on January 5, 1881; by the Civil Engineers' Club of Cleveland, on January 8, 1881; by the Boston Society of Civil Engineers, January 19, 1881, and by the Western Society of Engineers, on April 5, 1881. By this action, four local societies joined together for the purpose of sustaining a joint monthly publication of their proceedings.

The addresses issued by this committee at the time of the submission of the Articles of Association, so clearly define the objects then in view, and so clearly express the sentiments of the present chairman in regard to the future development of the Association, that he here transcribes a portion of that address as expressing also his own hopes and those which have commonly been held by the Board of Managers.

"The Association has been called into being by no narrow spirit. Many of its promotors believe that local engineering societies should be established and fostered in every center of population where the engineering profession is sufficiently strong to support one; thus bringing each member within the easiest possible reach of his society. They also believe that these local societies should be brought into affiliation by some association with a wider sphere of action, by means of which common purposes may be executed, and through which their energies may be stimulated to high professional aims.

"While many have been actuated by this broad spirit, the co-operation of these widely-separated societies has been, perhaps, mainly secured through a desire to effect an interchange of professional papers. To this desire the first number of the JOURNAL OF THE ASSOCIATION may be said to owe its origin.

"May we not hope that this act of co-operation is merely the initial stage in the development of an organization from which more than the interchange of papers will be realized, and for which we may reasonably predict a great future?

"We surely indulge the belief that the Articles of Association were not only begotten in a generous spirit, and are not only founded upon correct principles, but that they possess sufficient vitality and adaptability to permit growth in any direction which experience may indicate as desirable; that by wise counsel and the cultivation of a professional *esprit de corps*, an organization will ultimately be evolved from this beginning which will perform a work not now being done by any association in the land; a work beneficial to the participating societies as societies, and to every engineer who desires a better tone and higher standing for the engineering profession.

"In saying this we are not unmindful of the imperfections which are known to exist in the plan of organization, and of the probable existence of still other defects which are not now so apparent.

"We do not, however, believe these defects to be fatal. We think that any tendency endangering the prosperity or usefulness of the Association can be counteracted by the adoption of measures which come fully within the scope of action prescribed by the articles under which the Association exists.

"On behalf of the participating societies, the Board of Managers ask for the Association and its publication the earnest support of its friends, and the candid consideration of those to whom the wisdom of its creation has not as yet been made manifest.

"They also appeal to kindred societies for their co-operation, hoping thereby to establish a medium for the interchange of professional literature which will be enduring; and to create an Association which, by a unity of professional interests, will be perpetual in its benefits."

For many years no other local societies joined the Association. There was a time when it was difficult to secure a sufficient amount of matter to maintain the monthly publication in a creditable form. In the first volume of the JOURNAL the transactions and proceedings of each of the four societies were printed separately, with their individual society headings. This was done to satisfy a sort of local pride which these several societies had in seeing their matter placed distinct and apart from that coming from other societies. It made an awkward arrangement, however, to have the societies' proceedings scattered through the monthly numbers in this manner, and after the first volume the custom was abandoned, and the papers were printed in one portion and the proceedings in another portion of each monthly number without attempting to keep separate those of the several societies. It has always been customary, however, to indicate, at the beginning of each paper, the society before which it was read.

The following societies afterwards joined the Association:

The Engineers' Club of Minneapolis, July, 1884.
The Civil Engineers' Society of St. Paul, Minn., December, 1884.
The Engineers' Club of Kansas City, January, 1887.
The Montana Society of Civil Engineers, April, 1888.
The Wisconsin Polytechnic Society, June, 1892.

The society last named withdrew from the Association at the end of March, 1894, and since then eight societies have participated in the work of the Association.

When the Association was organized, the total membership of the four societies participating was less than 500.

Meetings of the Board have been held at irregular intervals. The following are the dates of all the meetings of the Board since the organization of the Association, with references to their records as printed in the JOURNAL:

First meeting, Cleveland, June 11, 1881. Vol. I, page 5.
Second meeting, New York, September, 4, 1884. Vol. III, page 329.
Third meeting, Chicago, April 15, 1887. Vol. VI, page 215.
Fourth meeting, Chicago, December 3 and 4, 1889. Vol. VIII, page 589.
Fifth meeting, Chicago, September 11, 1891. Vol. X, page 511.
Sixth meeting, Chicago, August 1, 2 and 3, 1893. Vol. XII, page 380.

While necessary expenses of the members of the Board, incurred especially for attendance on these meetings, have been paid from special assessments levied upon the participating societies, the meetings have usually been held at such places and times as to render these expenses as light as possible. During the past year the Board has transacted a considerable amount of business by correspondence, and while this is less satisfactory than the holding of meetings, it is also, of course,

very much less expensive, and it is usually found adequate to the transaction of routine business.

The business arrangement for the publication of the JOURNAL has varied from time to time. From November, 1881, to April, 1887, the JOURNAL was published by the Board of Managers, who were responsible for all bills incurred. During this time the JOURNAL was printed by Messrs. Atkin and Prout, of New York City, under a contract for composition, paper and presswork, and mailing, all bills being approved by the Chairman of the Board. During this time the Secretary of the Board was Col. H. G. Prout, a member of the firm named. From April, 1887, to April, 1890, the JOURNAL was published by the *Railroad Gazette*, under a standing contract, by which the Association paid the *Gazette* \$3.00 per annum for each copy of the JOURNAL sent to members of the participating societies, while the *Gazette* received all other sums realized, including the receipts from outside subscribers, from advertisements and from sales.

The *Gazette* further agreed to print, of each number, 50 per cent. more copies than were required to supply the mailing list. Of these extra copies, such as were not sold were to be turned over to the Board at the termination of the contract. This arrangement was made because Col. Prout had become editor of the *Railroad Gazette*, and could no longer act as Secretary of the Board. By this arrangement the work formerly done by the Secretary, at a salary of \$600 a year, was to be done by the *Railroad Gazette* without further compensation.

This arrangement for the publication of the JOURNAL proved satisfactory, and no controversy ever arose as to the quantity of matter published, or as to the character or amount of the illustrations accompanying the papers. At the meeting of the Board, held in December, 1889, the publication of the JOURNAL was let to Mr. John W. Weston, then editor of the *American Engineer*, Chicago, on a basis exactly similar to that of the contract with the *Railroad Gazette*, except that the annual assessment was made \$2.75 instead of \$3.00 per annum. This contract ran for nearly two years, or until the close of Volume X, in December, 1891. From that time on, the JOURNAL has been published by the Board, as at first, the Board paying all bills and employing a secretary at \$600 per annum.

On one or two occasions, the Board of Managers has prepared amendments to the Articles of Association, having in view the enlargement of the scope and province of the Association. Such amendments can become a part of the Articles of Association only on their formal adoption by a majority of the Societies composing it. In default of such action by the Societies, the Articles of Association remain as they were originally adopted, and they are so printed in the present number of the JOURNAL.

At the meeting of the Board of Managers held in Chicago, August, 1893, certain rules governing the action of the Board were adopted. In accordance with these, its officers can be elected by letter ballot, and without necessitating a meeting of the Board. The terms of office of the Chairman and of the Secretary were made two years, and the transaction of business by correspondence was recommended. These rules were published in Volume XII of the JOURNAL, page 381.

The propriety of the publication, by the Board, of the Index to Current Technical Literature has been called in question during the past year by some of the Societies, and not only the advisability of such publication, but also the authority of the Board to conduct it, has been challenged. The history of this department is as follows:

At the second meeting of the Board, held in New York, September 4 and 5,

1884, the present Chairman of the Board, being then the representative for the Engineers' Club of St. Louis, proposed to prepare the matter for such a department if the Board would consent to its publication. He was then engaged upon the preparation of an Index Rerum for his own use, and saw the desirability of making more accessible for ready reference the vast mass of journalistic, society and fragmentary engineering literature which was then coming before the profession. As an experiment, the Board agreed to publish this matter for one year, and the writer fulfilled his part of the contract and prepared the necessary notes, doing the work without compensation other than the receipt of the exchanges of the JOURNAL. The work of preparing the notes proved to be very onerous, and required a large amount of time, and at the end of the year the writer agreed to do the work for another year for the sum of $175, in addition to the exchanges, these latter being rated by him at a cash value of $25 per annum for permanent preservation. The experiment had proved a great success, so far as the readers of the JOURNAL were concerned, and many new subscribers had been obtained by reason of the publication of these notes. The Board therefore voted unanimously to continue this department and to pay the price named for preparing the notes. The writer did the work for the second year himself, receiving slight assistance from a few public-spirited engineers who sent him some notes which he would not otherwise have obtained. While he has repeatedly requested the Board to assist him in getting rid of this burden, no one has as yet been found who was willing to undertake the responsibility for the compensation which the Board has continued to make, namely, $175 per annum and the exchanges. Since the second year, therefore, the undersigned has paid out, for such assistance in the preparation of these notes as he has been able to obtain, the full amount received from the Board for this department. Most of the work has still been done in his office, by himself and his immediate assistants, and this is the situation at the present time. At all the meetings of the Board held since the inauguration of this department, it has been unanimously voted to continue the publication of these notes at the rate named, and in the absence of other volunteers the writer has been requested to continue in charge of this department. The question of abandoning the department has, during the present year, been submitted by letter to the members of the Board, and but two votes have been registered against its continuance. This department partly pays for itself in the increased number of subscribers which it brings to the JOURNAL and in the better facilities which it affords for the display of advertisements. If an Index Department was needed ten years ago, much more is it needed to-day, and this demand has been recognized in various technical lines by the starting of other indexes of technical literature. That published by the *Engineering Magazine* is now very complete, but it lacks that which characterizes the Index published in this JOURNAL, namely, a note appended to each item, and prepared by a competent engineer, describing the scope, significance and value of the article indexed. Hence, while it is far more complete than the one published in the JOURNAL, it fails to give that information which enables one consulting it to decide whether or not it would be worth his while to consult or obtain a copy of the article. This is exactly the mental query which the Index notes in the JOURNAL are designed to answer. Furthermore, the Index published in the JOURNAL has the great advantage of an alphabetical arrangement, and of annual recompilation under a *single* alphabetical arrangement. While our notes make no pretense of being "complete," it is believed that they contain nearly all that is valuable in the line of *civil* engineering, and much in the lines of electrical and mechanical engineering, in the

English language, and some of that in the French and German. I believe the nearly unanimous opinion of the readers of the JOURNAL is that this department is well worth all it costs, and that its abandonment would be a misfortune. If the undersigned had not felt that this were true, he would long since have given up the work.

Some misapprehension appears to exist respecting the conditions under which the bound volume of the Index notes was published a few years ago. At that time the Index Department had been conducted for seven years, and seven annual index summaries had been issued. To consult these, one was obliged to look through seven different alphabetical lists, and it was thought that there was a sufficient demand to warrant the republication of these seven annual summaries in one new alphabetical arrangement, to be published in book-form, cloth bound. The then Chairman and Secretary of the Board, together with the undersigned, discussed the matter by correspondence, acting however, as members of the Board. It was decided that if as many as five hundred subscribers could be obtained for such a volume, at $2.50 each, the Board could afford to proceed with the work. Circulars were therefore sent out, and after about three hundred and fifty subscribers had been secured, so much time had been lost that it was thought best not to wait any longer, for fear the matter, by age, would lose in value. At this time it was supposed that a considerable profit would result from such a publication, and this profit would have gone into the treasury of the Board. The Chairman and Secretary felt, therefore, that it was safe to order the compilation made, and the undersigned immediately set to work to prepare the matter. This proved to be a greater work than was anticipated, since it was found necessary to make an entire re-arrangement of the headings, and to supplement fully with cross-references. As there were over 11,000 of these notes, each of which had to be cut out and pasted on a separate card, and as all of them had then to be re-arranged, often with new headings written in and with all the necessary cross-references added, the work consumed considerable time, and was somewhat expensive. The cost of composition also was excessive, as three fonts of type were in continuous use, and high prices had to be paid for competent compositors. Furthermore, in order to sell the copies which had not been subscribed for, a large outlay became necessary in the way of printing, postage and clerk hire, in order to bring the volume to the attention of engineers. The undersigned took his pay entirely in published volumes, and succeeded in placing about one hundred and fifty copies, all told, amongst the members of the Engineers' Club of St. Louis. The other societies in the Association, having less personal interest in the work, took fewer copies. The result was that the receipts were considerably less than the total expense, and the volume has never yet paid for itself. Since it was a losing venture, the Board has never been asked to assume the responsibility of its publication, and the loss has fallen on the three gentlemen who undertook the work. A number of copies still remain in the hands of Mr. Weston, and these are sufficient to reimburse him, if sold, as, eventually, they doubtless will be. The Board, however, has had no responsibility in this matter, and has incurred no expense.

II. REVIEW OF THE WORK OF THE PAST YEAR.

At the meeting of the Board of Managers at Chicago in August, 1893, Mr. Benezette Williams, who had been Chairman of the Board from the beginning, declined a re election to that position. In accordance with the new rules of the Board then adopted, the undersigned was subsequently elected Chairman by letter

ballot, and Mr. John C. Trautwine, Jr., of Philadelphia, was elected Secretary. These officers assumed charge of the publication of the JOURNAL with the January number of 1894. As they were elected for two years, their duties will continue for another year. While the duties of the Secretary necessarily involve a certain amount of editorial supervision of the matter published in the JOURNAL, his meagre salary does not warrant the Board in expecting him to spend very much time upon the work. It is, therefore, due to the present Secretary that the Chairman should here publicly recognize the benefits of his incessant labors in behalf of the JOURNAL, and express the sincere appreciation and grateful acknowledgment which those labors so justly deserve. He has in a marked manner devoted himself continually to the best interests of the JOURNAL in particular and of the Association in general, as he understood them, and has cheerfully and heartily responded to all requests and suggestions made to him by the Chairman and by other members of the Board. The benefits of his work are clearly seen in the JOURNAL itself. The editorial supervision of the matter printed in the JOURNAL has, I believe, been of a higher grade than any hitherto given to this publication, and the two new departments of the "Contribution Box" and "Library" have been mostly contributed by the Secretary.

The mailing lists of the JOURNAL, at the close of 1893 and of 1894 respectively, compared as follows:—

	Dec. 1893	Dec. 1894
Boston Society of Civil Engineers	325	353
Western Society of Engineers	354	337
Civil Engineers' Club of Cleveland	184	187
Engineers' Club of St. Louis	159	163
Civil Engineers' Society of St. Paul	28	34
Engineers' Club of Minneapolis	31	33
Engineers' Club of Kansas City	21	25
Montana Society of Civil Engineers	40	42
Wisconsin Polytechnic Society	42	
	1,184	1,174
Extra copies to members of Board of Managers, five each	80	70
Advertisers	7	27
Exchanges	77	110
Subscribers and Complimentary copies	140	
Subscribers		176
Complimentary copies		15
	1,488	1,572

Besides this, many specimen copies have been sent out, with a view to increasing the circulation of the JOURNAL and securing advertisements; and authors of papers receive five copies of the JOURNAL containing them. As a rule, 2,000 copies of each number have been printed.

The Journal for 1893 (Vol. XII) contained

Papers	576	pages
Proceedings	82	"
Index, advertisement and blank pages	344	"
Covers	48	"
Title	8	"
Total	1,058	"

The volume just closed (Vol. XIII, 1894) contains a total of 1,290 pages of printed matter, 86 cuts and 54 plates and full-page cuts, as follows:

	Papers.	Contribution Box.	Library.	Proceedings.	Index & advertisements.	Total.	Number of cuts.	Plates and full-page cuts.
January . . .	58	4	2	20	24	108	8	5
February . .	73	3	4	18	30	128	2	3
March . .	45	4	3	14	26	92	8	1
April	32	2	2	12	24	72	0	3
May	42	4	2	8	24	80	11	2
June	45	1	2	4	24	76	9	10
July	68	3	5	2	24	102	2	13
August . . .	47	1	4	8	26	86	14	6
September . .	79	2	3	6	26	116	9	3
October . . .	66	2	4	6	26	104	2	0
November .	57	1	6	8	24	96	10	6
December . .	41	1	2	14	108	166	11	2
	653	28	39	120	386	1226	86	54
Covers						48		
Index to volume						16		
Total						1290		

The number of pages exceeds, by 232, or about 22 per cent., that of Vol. XII, 1893, which was the largest that had appeared up to that time. In 1894 a larger type was used, but the size of the page was also increased, so that the page contains the same amount of matter as before.

Many of the illustrations are of a degree of excellence far beyond anything hitherto obtained in this publication.

At the close of 1893 the Journal contained 7 advertisements, occupying 3 pages, and netting the Association about $100 per annum. The number for December, 1894, contained 25 paid advertisements, occupying about 10 pages, and netting about $850 per annum. In this respect the Association has received important aid from members of the Societies, notably the Boston Society of Civil Engineers.

In order to encourage the societies in obtaining advertisements for the Journal, inducements have been offered from time to time in the way of sharing with such societies the profit from such advertisements. The rule of the Board now is, that 50 per cent. of the net income from all advertisements secured by any society in the Association shall be credited to the account of such society on the books of the Board, provided this credit be requested at the time the advertisements are obtained.

During the past year the Western Society of Engineers for a second time considered the propriety of withdrawing from the Association. As the Articles of Association require that notice of withdrawal shall be given three months previous to the end of the fiscal year, it was voted by the members, in meeting assembled, to give such notice; but the question was then submitted to the full membership for decision by letter ballot. The movement in favor of withdrawal was due, not to dissatisfaction with the conduct of the Journal, but to the impression that the best interests of the Society demanded this step preparatory to an anticipated career of wider influence as a national organization. The result of the letter ballot, however, was 137 to 70, or nearly two to one, in favor of remaining in the Association. This result is, of course, most gratifying to the members of the Board and to the other societies in the Association. So far as the Chairman is aware, no other society now in the Association contemplates withdrawing from it.

The Chairman takes great pleasure in announcing the fact that, as the result of a circular letter addressed, in October last, to the outstanding local and sectional societies, inviting them to become members of the Association, two other local engineering societies of high professional standing have recently joined the Association, namely, the Association of Engineers of Virginia, and the Denver Society of Civil Engineers. The total membership of these two societies is now about 60. The Technical Society of the Pacific Coast, with about 150 members, has voted to join the Association. The Engineering Association of the South has postponed for one year its decision as to joining the Association, but it is probable that at the end of that time it will apply for membership. Other local societies of good professional standing are considering the question of joining the Association, so that it is probable that within a year or two the number of societies co-operating will be materially increased.

III. Financial Statement for the Past Year.

The following is a statement of the receipts and expenditures for the past year, as shown by the books of the Secretary:

CASH, 1894.

Dr.

To Assessments	$3,636 00	
" Subscriptions	298 00*	
" Sales of Journals	181 51	
" Advertisements	760 50	
" Sales of Reprints†	229 75	
" Interest on Deposits	3 44	
" Express charges refunded	2 92	
		$5,112 12

Cr.

By Edward Stern & Co., printers	$3,098 82	
" Illustrations	636 00	
" Secretary's Salary	600 00	
" Commissions on Advertisements‡	89 50	
" Discounts on subscriptions	17 20	
" Traveling expenses	30 69	
" Typewriting	24 00	
" Mimeographing, etc.	50 30	
" Freight from Chicago, hauling, unpacking etc., on back numbers of Journal	118 84	
" Stationery	33 83	
" Messenger service	6 90	
" Postage	55 43	
" Notary's fees	1 50	
" Copyright on January Journal	50	
" Telegrams	7 33	
" Express charges	10 84	
		$4,781 68
Cash Balance, January 1, 1895		330 44

* $176.55 of 1894 subscriptions were collected by the former administration. See account below. The balance, so far as collected, and a few 1895 subscriptions, are included in the amount here given.

† About one-third of this item is profit to the Association.

‡ This item includes $70.75 to the Civil Engineers' Club of Cleveland.

Mr. John W. Western, the former Secretary of the Association, renders the following account of his receipts and expenditures since the close of his account for 1893:

RECEIPTS.

From subscriptions	$176 55	
" Engineers' Club of Kansas City, on account of assessments	50 00	
		$226 55

EXPENDITURES.

Postage, express charges and incidentals, transferring office	$29 53	
Secretary's salary for January	50 00	
Sorting, packing and shipping back files and materials, 45 cases	75 00	
		$154 53
Balance		$72 02

Subject to the approval of the Board of Managers, I have accepted from Mr. Weston, in settlement of this account, fifty bound copies of Vol. I. of the Descriptive Index of Current Engineering Literature, reprinted from the JOURNAL OF THE ASSOCIATION, and covering the years from 1884 to 1891 inclusive. The selling price of these copies is $2.50 each, or $125.00 in all.

The cost of the various items of the JOURNAL for 1894 is given in the following table:

Cost of JOURNAL during 1894.

	1	2	3	4	5	6	7	8	9	10	11	12
	Printer.*	Illustrations.†	Index Compilation.	Sum of 1, 2 and 3.‡	Wrappers.	Postage on JOURNAL.	Mailing.	Secretary.	Sundries.§	Total.	Number of Pages.‖	Cost per Page.
January	$341 35	$69 25	$14 58	$425 18	$3 50	$8 04	$5 89	$50 00	$34 49	$527 10	112	$4 71
February	343 74	. . .	14 58	358 32	4 09	8 74	8 89	50 00	34 49	464 44	132	3 50
March	226 68	6 50	14 59	247 77	4 00	63 52	28 40 ¶	50 00	34 49	428 18	96	4 46
April	185 32	13 00	14 58	212 90	4 00	44 68	7 40	50 00	34 48	353 46	76	4 64
May	193 69	32 50	14 58	240 77	4 00	41 79	5 90	50 00	34 49	379 95	84	4 53
June	203 49	104 90	14 59	322 98	4 00	7 20	6 40	50 00	34 49	425 07	80	5 31
July	410 37	128 40	14 58	553 35	4 00	7 36	5 60	50 00	34 49	654 80	106	6 18
August	214 21	104 45	14 58	333 24	4 00	5 17	8 39	50 00	34 48	435 28	90	4 72
September	271 18	52 50	14 59	338 27	4 00	9 34	5 16	50 00	34 49	411 26	120	3 67
October	254 70	4 00	14 58	273 28	4 00	9 12	5 90	50 00	34 49	376 79	108	3 49
November	296 88	119 10	14 58	430 56	4 00	13 47	6 50	50 00	34 49	539 02	100	5 39
December	612 00	17 00	14 59	643 59	4 00	11 27	5 90	50 00	34 48	749 24	186	4 02
	$3,553 61	$651 60	$175 00	$4,380 21	$47 50	$232 70	$100 33	$600 00	$413 85	$5,774 59	1290	$4 48

* The figures in Column 1 include composition, paper, presswork, binding and corrections.
† The figures in Column 2 include preparation of cuts, and paper and presswork on insets.
‡ The figures in Column 4 may be said to represent the cost of *manufacture* of the JOURNAL.
§ The figures in Column 9 include all expenditures of the Association (stationery, postage, circulars, etc.) chargeable to the JOURNAL and not otherwise noted. They do not include expenses on back numbers or cost of preparing reprints of papers.
‖ The figures in Column 11 include 4 cover pages in each number and 16 pages in index to volume.
¶ This includes $22.50 for re-arranging mail list in alphabetical order.

The total cost of the JOURNAL for 1893 was $4,517.78, or $4.27 per page.

Owing to a ruling by the Post-Office Department to the effect that members receiving society publications in consideration of dues were not considered as *bona fide* subscribers, and that therefore such journals as our own were not entitled to second-class or "pound" rates (1 cent per pound), we were compelled to pay third-class rates (1 cent per 2 oz.) on the March, April and May numbers. See "Contribution Box," July, 1894, p. 397. This entailed an additional expense of about $125. Deducting this, for purpose of comparison, we find the total cost of the JOURNAL for the year 1894, $5,649.59, or $4.38 per page.

In the report of expenditures for 1893, office expenses, postage and mailing are given in one amount. Estimating postage (at pound rates) and mailing for 1893 upon the basis of 1894, we have left, as office expenses, $110.63, and find that the cost of publication proper compared as follows:—

	Total.	"Office Expenses."	Publication.	Pages.	Cost per page.
1893	$4,517 78	$110 63	$4,407 15	1,058	$4 16
1894	5,774 59	413 85	5,360 74	1,290	4 16

The increase in "office expenses" or "sundries," for 1894, is chiefly due to the inauguration of an active policy of advertising to the profession, by circulars, sample copies, correspondence, etc., the merits of the JOURNAL, with a view to increasing its advertising and subscription patronage and of securing the co-operation of outstanding societies. As will be seen from facts already stated, the increase in receipts from advertisements alone, already more than covers the entire office or sundries account, while, in addition to this, a considerable increase has been made in our subscription list, and new societies have been brought into the Association. It is believed, moreover, that the results of this policy, which is still being vigorously pursued, will continue to be felt, and in a greater degree, in the future.

The cost of the Index to Engineering Literature, for 1894, was approximately as follows:—

Compilation		$175 00
Composition		
January to November, inclusive, 90 pages at $2.75 . . .	$247 50	
December, 90 pages at $2.75	247 50	
		495 00
List of periodicals indexed.		
Composition, four pages at $2.75		11 00
Charge for type standing, four pages, say		7 00
Paper, presswork and binding,		
11 months at 12 pages each 132 pages, say 8 forms, at $17.00	136 00	
December, 94 pages, say 6 forms at $17.00	102 00	
		238 00
		$926 00

With the present number an experiment is being made with the use of the linotype machine, in place of type-setting, for the composition of the index notes, and it is expected that, if the results of this prove satisfactory, a reduction of nearly fifty per cent. in the total cost of the index can be effected.

The Contribution Box and Library departments for 1894 contain, together, fifty-one pages, and their actual cost, for composition, presswork and binding, was about $135.

It has been urged that the conduct of these two departments is beyond the province of the Association, the "primary object" of which, by our Articles, is defined to be the publication of the papers and proceedings of the participating societies; but it would seem to be within that province as viewed by the spirit of the Articles of Association, which empower the Board of Managers to publish in the JOURNAL excerpts from other journals, and, if the departments in question can be made to add to the value of the JOURNAL so as to increase its revenues and thereby aid in its publication, they are surely within the *letter* of the Articles.

It is much to be regretted that the members of the societies have not more generally acted upon the invitation, extended in each number of the JOURNAL, to send to the Secretary, for the Contribution Box, "such matters of general interest as may come to their notice."

As stated in the JOURNAL for January, 1895, it was hoped that the members would enable the Secretary to publish, in the Contribution Box, "those little matters, hardly of sufficient dignity or bulk to form the subject of a formal paper, which yet often rival, if they do not surpass, these more venerable documents in interest and utility." It is believed that if the members would contribute freely from their experience in this way they would greatly increase the value of the JOURNAL and its claims upon outside subscribers.

The following table shows the numbers of pages of papers contributed during 1894 by the several societies composing the Association, together with the number of members in each society at the close of October, the percentages which these form of the total membership, and the number of pages (or, to be more exact, the fraction of a page) contributed per member. For purposes of comparison, corresponding figures are given for the Engineers' Club of Philadelphia and for the Engineers' Society of Western Pennsylvania, two of the largest local and sectional societies still outstanding.

Society.	Number of Members, October, 1894.	Percentage of Total Membership.	Pages.	Pages per Member.
Boston	346	30.5	272	0.789
Chicago	297	26.2	152	0.512
Cleveland	184	16.2	70	0.380
St. Louis	173	15.3	83	0.480
St. Paul	32	2.8	24	0.750
Minneapolis	33	2.8	21	0.635
Kansas City	26	2.3	10	0.385
Montana	42	3.7	21	0.500
Association	1,133	99.8	653	0.576
Philadelphia	429	. .	199	0.465
Western Pennsylvania	455*	. .	235	0.516

The question of making a special assessment on the Societies in the Association in order to balance the accounts of the year, was recently submitted to the members of the Board, and it was unanimously voted to make such an assessment. It is probable that no special assessment need be made, to cover the needs of the present year, and that by further increase of our subscription and advertising

* From list of members for 1894.

patronage, the cost of the JOURNAL to the Societies can hereafter be kept within the customary price of $3.00 per annum per member.

IV. PROSPECTS FOR THE FUTURE.

The Board of Managers has often been requested to formulate some scheme by which the province of the Association may be enlarged and its work extended. It has been, for instance, proposed to hold an annual convention of the members of the participating societies, and that the union between these societies be made more vital. At present the joint publication of proceedings and transactions is all that these societies have in common. It is a serious question whether it is wise to make their union more intimate and vital. The societies in the Association are, in their nature and of necessity, local or sectional They include in their several memberships technical practitioners of all kinds, and their peculiar province is to serve the purpose of bringing together in their several localities all persons professionally engaged in scientific and technical employments. For purposes of national organization these same individuals are organized along their several lines of practice, and there is little demand for national organization other than that afforded by the present national societies.

Beyond this evident advantage, it is doubtful if there exists any real need for organic reunion. Each local society should have its own independent autonomy, designed to serve the particular local interests of its own vicinity, and should be untrammeled by any higher or outside authority or influence. It seems to the undersigned, therefore, that these local societies are already reaping, in the joint publication which they now support, and which in turn materially aids in sustaining these local societies themselves, practically the full measure of the advantages of united action.

Respectfully submitted,

J. B. JOHNSON, *Chairman.*

ASSOCIATION
OF
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NOTES ON EUROPEAN WATER SUPPLIES.

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IT has been my good fortune during the past year to visit a large number of the leading water works in central and western Europe, and I propose this evening, not to give you a systematic or exhaustive account of them, but simply to mention some of the points which have specially interested me, and which, I trust, may also prove of interest to you.

The question of securing an adequate supply of pure water is by no means confined to the western hemisphere, and the activity with which projects are being discussed and carried out in European capitals was a constant source of surprise to me, for we are apt to think of European cities as places of slower growth and more fixed habits, where public works would progress more slowly.

In London a royal commission has just been considering the question of the probable needs of the eleven millions of people which they estimate that London will contain in 1931.

Birmingham is just commencing the construction of an aqueduct which is to supply it with pure mountain water from Wales, and, on the continent, Brussels is considering the project for a water supply for the greater metropolis which it is proposed to form out of the city and its suburbs.

Hamburg last year completed the filters which had long been con-

templated, and the construction of which was hastened by the awful epidemic of cholera which ravaged the city in 1892. Berlin also is largely extending its works. In Vienna the supply of mountain spring water has recently been increased, and still other projects of much greater magnitude are being considered for the supply both of the central city and of the surrounding towns. Paris, which had so long suffered from the lack of an adequate quantity of water for domestic purposes, completed in 1892 an additional spring water supply with a minimum yield of twenty-three million gallons, and still greater projects are now being discussed for execution as soon as the needs of the population exceed the present supply.

All of these schemes differ, in one striking respect, from corresponding projects in America. The quantity of water provided per head is always less than one half, and frequently not more than a quarter, of that considered necessary for American communities. The causes of this difference are not altogether clear. In some instances the smallness of the European consumption may, in a measure, be attributable to a smaller proportion of water-closets, or to the fact that the entire population is not provided with flowing water in private apartments. But, after making all possible allowance, there is still a wide discrepancy which cannot be accounted for by the greater comforts or cleanliness of the American cities. Fire protection in Europe is upon a radically different basis from that in America. In all European capitals the construction of other than fireproof buildings is strictly prohibited, and fires, as we understand them in America, can hardly be said to exist. In Berlin, during the past year, the quantity of water which supplied all the necessities of the fire department for extinguishing fires and other purposes was less than three thousand gallons daily, and in no other German city, except Hamburg, was so large a quantity required.

American water pipes are so planned throughout as to allow a concentration of water for fire purposes. European water pipes serve only for the distribution of water for domestic purposes, and there is no provision (or, if there be any, it is of a most rudimentary character) for concentration of the large volumes of water which would be necessary for extinguishing the fires which are of almost daily occurrence in American cities. This system permits the use of smaller pipes, and thus, no doubt, reduces the leakage from imperfect joints, and, at the same time, by greatly decreasing the cost, allows more attention to be given to the quality of the work.

Another element which, in Europe more than America, tends to restrict the use of water, is the use of meters. In German cities particularly, it is often the case that no water is sold except by meter; and in Berlin over 86 per cent. of all the water pumped is actually accounted

and paid for, leaving less than 14 per cent. for use for all public purposes, such as street sprinkling, public fountains, sewer flushing, etc., as well as for waste.

The study of the quality of water supplies has received a new impetus since the cholera epidemic of Hamburg two years ago. This epidemic, as you remember, caused, in less than a month, the death of eight thousand persons in Hamburg, while the neighboring cities of Altona, Harburg and Wantsbeck remained substantially free. The water supply of Hamburg at that time was drawn unfiltered from the river Elbe at a point slightly above the city, but where it was subjected to occasional pollution from Hamburg's own sewage, as well as to the constant but more remote pollution from the fifty cities, each with more than twenty thousand inhabitants, upon the watershed of the river and its tributaries, with an aggregate population of about six millions, not including the smaller towns or the country districts. The watershed of the Elbe, above Hamburg, has an area of about 52,000 square miles, and the annual rainfall is 28 inches.

The other cities mentioned had other and better supplies, and their escape from the cholera was attributed by the Imperial Board of Health, after a most thorough examination, to this fact. Since that time, Hamburg has pushed to completion, at a cost of $2,300,000, the filters previously projected, and at the present time the city has one of the finest water supplies of Germany. The effect of this Hamburg-Altona incident was not confined to the local conditions. It has resulted in many radical changes throughout the German Empire. Two years ago Hamburg was the only city in Germany drinking ulfiltered surface water, but there were a number of other cities, such as Stettin and Lubeck, which filtered their waters at high rates and under conditions other than those found most favorable where filtration has been most carefully considered. Probably as a result of its investigations at Hamburg and Altona, the Imperial Board of Health issued an order prohibiting the use of unfiltered surface water for drinking in any German city, and prescribing in those cases where filtration is employed the conditions under which such filtration should be executed. The order prescribed, for instance, the rate of filtration, the minimum depth of the filtering medium, the treatment of filters at the times of cleaning, and also suggested that the effluent from each single filter should be daily examined bacterially by some officer appointed by the city, and, if possible, permanently connected with the water works. Some of these rules were objected to by the water works engineers on the ground that they could not be carried out without too serious disturbance of existing arrangements. Afterwards a conference was arranged between the Board of Health and a committee selected by a permanent society

of water works engineers (Deutscher Verein von Gas- und Wasserfachmännern) and a new set of rules, differing somewhat in detail from the first ones, was prepared. These rules have since been issued by the Minister of the Interior, and they are binding upon all German water works. In accordance with them those water works which had filters incapable of conforming to the requirements, have, in every case, so far as I know, during the past year, reconstructed their works in a more or less thorough manner to meet the requirements, and the bacterial examination of water commenced in most cases on the first of April, 1894. In this connection I may say that the laboratory for the examination of water in connection with the Hamburg works is one of the best equipped which I have ever seen. It is placed in a separate two-story brick building, which contains rooms for the various departments, and every facility for conducting the large number of tests which the rules require.

Berlin also draws its water from rivers, and filters it. The populations upon the Havel and the Spree are less than that upon the Elbe, but the watersheds are also less, so that the pollution in proportion to the volume of water is not inconsiderable.

The filtration at Berlin is effected by some thirty acres of filters which have been vaulted over as a protection from winter weather. Formerly open filters were used, and much difficulty was experienced on account of ice; in 1889, during an unusually cold period, the filters became so far unserviceable, and the water supply deteriorated to such an extent, that the city suffered from a considerable epidemic of typhoid fever. Since that time the use of open filters has been abandoned as fast as new covered filters could be substituted for them.

Among the thirty German cities which either have more than one hundred thousand inhabitants, or supply water to that number of persons, there are eleven which supply filtered water, the raw water being in almost every case drawn from rivers. The other nineteen cities are all supplied with ground water, but the aggregate population so supplied is somewhat less than the population in the eleven cities supplied with filtered water. The supply of ground water in the volumes required by large cities, has received a great deal of attention in Germany. Dresden, with 300,000 inhabitants, is supplied from a filter gallery 4,900 feet long and 26 inches in diameter, extending along the Elbe about 70 feet from the river and about 10 feet below low water. The walls of this gallery are built with perforations, and are surrounded with coarse gravel and the natural material of the river bank. This gallery has been in use since 1875, and has always given an abundant supply of entirely satisfactory water. The level of the water in the gallery is reduced by pumping only to about 5 feet below the river, and

at the time of my visit there were nearly 12 feet of water in the pump well. These works were built by Engineer Salbach, and it his idea that the six or eight million gallons of water drawn come entirely from the land side, and that only insignificant quantities, if any, of the river water find their way to the pumps. It is his idea that there is an extensive bed of gravel all along the river for miles, reaching up into Bohemia, and that in this gravel there is another river flowing beside the Elbe with lower velocity but vastly larger cross-section, and that it is the water of this underground river which he obtains. It is on this account that the projected extension of the Dresden works is placed on the other side of the river, and some miles away, in order to tap another portion of this subterranean river, as he feared that any extension in the present location would tend to unduly lower the ground water level and to cause infiltration of water from the river. Some miles above Dresden the Elbe flows between rock walls, and, so far as one can judge, over a rock bed, through the so-called Saxon Switzerland. It was my first thought that these rocks would act as an obstruction to Herr Salbach's underground river, and that the river, if such existed, must have its origin below this point, but Herr Salbach informs me that the stone at this point is mainly porous sandstone, and is capable of allowing the passage of water, and, in addition, there may be fissures. It seems to me, however, that similar objections might rightly be raised to the theory that similar underground rivers are flowing parallel to many New England streams.

The newer ground-water supplies have substituted separated wells with suction tubes for the galleries, a substitution which, it is said, greatly cheapens their construction for a given result. Leipzig, with 360,000 inhabitants, is supplied by such a series of wells located some thirteen miles from the city. The water is taken from gravel beds which probably mark an old course of the Mulde and which still carry large volumes of water having their origin in that river, and so far as they are not diverted for water supply, reverting to it lower down. This is a particularly interesting case, for the surface water from this neighborhood, what little there is, does not go into the Mulde at all, but flows in the other direction into the Saale. At this point the Mulde makes a little detour, and the Saale's watershed goes almost to its banks. The old Mulde channel thus lies, for a considerable distance, in the present Saale watershed. The country all about, as far as the eye can reach, is perfectly flat, except in a few places where ledges crop out. The surface shows a slope of about one in a thousand. The watershed of the little brook passing the works is quite insignificant and bears no relation to the supply, and there is no large body of water above the surface for miles. This old river bed is about three miles wide, and the gravel in

it is from 50 to 70 feet deep. The wells constructed by the city reach in a straight line nearly across the entire width of this gravel. The first wells, 140 in number, covered about one third the distance; afterwards 90 additional wells, 33 feet apart, were put down, and the latest addition which I saw in course of construction consists of 94 wells 60 feet apart.

The method of digging these wells is to put a 12-inch cast-iron pipe down to the depth required, digging out the sand from the centre as the pipe sinks; afterwards the permanent 7-inch pipe with a strainer about 16 feet long, is introduced, and inside of that an independent copper suction pipe reaching nearly to the bottom. In addition, a three-quarter-inch pipe is provided for taking samples and ascertaining the water level. When all is in position, the 12-inch pipe first put down is drawn up. Water is now pumped from the well by an electric pump, operated from a trolley running the length of the extension. With rapid pumping much sand is at first drawn until the particles which cannot pass the rather coarse sieve form a gravel layer around that point and hold back the sand without further trouble. By rapidly pumping on four wells at a time by means of the electric pumps the ground-water level is lowered far enough below the surface to allow the permanent collecting pipes to be placed. For this collecting pipe rubber connections are everywhere used instead of lead. They are said to be cheaper and tighter, and they can be taken apart at any time without the slightest damage to the pipe. They have also the advantage of greater flexibility. On a 2-foot pipe, a rubber ring, like a bicycle tire, but solid, and one-half as large again as the opening between the bell and spiggot, and of the exact diameter of the pipe, is placed on the end of the spiggot and is rolled into the bell, enclosing and flattening the rubber ring. The joint so made is air-tight for vacuum, and will hold at least four atmospheres of pressure without leaking. The joint is made complete in two minutes under water if necessary, and, so far as known, it does not deteriorate with time. It can be taken apart and readjusted as often as desired. On the regular distributing pipes in the city, lead joints are ordinarily used, but I was told that on bridges, where flexibility was desired, rubber had been used with entirely satisfactory results. The collecting pipe from these wells discharges into the pump well, which is lower than the point to which it is proposed to lower the ground water, and any air which may accumulate in the pipes is removed from time to time by an air pump connected with the highest points on the pipes. When properly arranged in this way, syphons can be used with lifts up to twenty-six feet. The water obtained in this way is of satisfactory quality in every way except that it contains a little iron. The first two series of wells were so built that each well could be

separately tested for iron, and the worst wells were shut off. This arrangement has not, however, been entirely satisfactory, and this year no provision is made for shutting off single wells. It is found that in passing through the thirteen miles of pipe and conduit (about one-half of each) to the distributing reservoir and over the measuring weirs, the water becomes thoroughly aërated and the iron is precipitated. Filters have just been constructed through which this water will in future be passed at an extremely high rate, and it is believed that no further difficulty with iron will be experienced.

A record is kept of the height of water in the different wells, and also of that in other wells in the vicinity. Pumping for years from the first section has not in the least lowered the water level in the other sections; and the flow of ground water, while slower below the wells, still continues in the same direction, showing that even now the wells do not intercept all the water there. The entire capacity of the plant is now estimated at 16,000,000 gallons daily. The old works, without the last addition, have yielded as much as 11,000,000 gallons.

Herr Thiem, consulting engineer for the Leipzig and other works, has an interesting method of estimating the capacity of a ground water supply. He sinks three wells equidistant from each other in the form of an equilateral triangle. No water is pumped from them at first, but the water level is observed carefully for some days. From these observations he calculates the direction of the slope, and consequently of the flow, of the ground water, as follows: He calculates the point, on a straight line joining the wells having the highest and lowest water levels, where the water level is the same as it is in the third well. Joining this point with the third well gives a line at right angles to the line of flow. A fourth well is now sunk in exactly this direction, that is, the line of flow, from one of the first wells, and the higher well is dosed with a quantity of salt solution, followed by enough water to force the salt into the surrounding gravel. Samples of water are now taken at intervals from the lower well, and analyses show when the salt passes. From this is calculated the velocity of the ground water, and, in connection with the cross-section of the gravel, the quantity of water passing is estimated, and this is regarded as the capacity of the source, making allowance for variation of flow at different seasons. Herr Thiem has no confidence in pumping tests of wells short of years of continued use.

At Charlottenburg, a suburb of Berlin, a ground water is used which contains even more iron than that at Leipzig. In this case there is no flow through a conduit to oxidize the iron, and instead the water is taken through coke towers at a rate of 100,000,000 gallons per acre daily. The water, in passing through the coke, is everywhere in contact

with air, and it is found that the water so treated can be passed through an ordinary sand filter at a rate of 25,000,000 gallons per acre daily, yielding an effluent entirely free from iron. The capacity of this plant is 13,000,000 gallons daily. This process, which has been perfected by Engineer Piefke, is also applied to a number of smaller supplies, and for removing the iron from the well waters used by a number of breweries in Berlin and in Breslau.

Munich has a ground-water supply which is collected in still another way. The original supply was a series of springs along the side of a ravine in cultivated, wooded and rather elevated land, just where the foot-hills of the Alps commence. The soil on the country back of this ravine undoubtedly furnishes the water, and is generally pervious, consisting chiefly of gravel, with more or less clay in places and a layer of slate below. The country is comparatively level, but is cut by the ravine of a river, 150 to 200 feet deep, which goes some distance below the intercepting layer of slate into the gravel below. Along one side of this valley and above the clay were natural springs, which were first taken for Munich's supply, but it was found that the bulk of the water discharged through crevices in the slate below the surface into the river, and extensive galleries above the clay were built to intercept it. The bottoms of these galleries are of concrete, and their roofs are stone arches 5 to 6 feet high. A perforated tile pipe, 18 to 24 inches in diameter, is laid directly under the gallery and communicates with it at intervals. Under ordinary circumstances all of the water flows in the lower pipe, but when the flow exceeds its capacity the surplus flows through the gallery above. In a few cases the drain pipe was omitted altogether. Except near the outlet, the stone arch over the gallery is laid without mortar, and is surrounded by gravel to allow the free admission of water. The whole is sunk in a clay to a depth of about 3 feet, but varying with the irregularities in the surface of the clay.

There are at present about 7,800 lineal feet of these galleries in use, and of these 4,800 feet are walled without mortar, but the remaining 3,000 feet are also supposed to collect considerable water. These galleries must be from 100 to 150 feet below the surface. In March, 1887, the lowest yield from them was 15,000,000 gallons per day, and almost as low a figure was obtained in October, 1893, both times for a few days only. In wet seasons the springs have yielded as much as 32,000,000 gallons daily for short periods, and the average quantity used by the city is about 12,000,000 gallons per day. The flow of the springs is always free, and so much of the water as is required is sent to the city, the rest being wasted into the river. The capacity of the aqueduct is 23,000,000 gallons per day. The length of the conduit to the reservoir is nineteen

miles, and the average grade is 1:880. The conduit, for the most part, is $4\frac{1}{2}$ by $2\frac{1}{2}$ feet in cross-section. It is seven miles from the distributing reservoir to the town, so that the entire distance is about twenty-six miles. The cost of the works was $2,100,000.

Among the world's great capitals, Vienna has a unique supply. Its source is in the high mountains near the line of the Semmering railroad, about sixty miles from the city. The mountains are of dolamite, with streaks of pure limestone, all of tertiary origin. Under the whole is a continuous impervious layer of slate, just above which the springs are located The bulk of the stone is solid, but there are many fissures through which the water flows. The surface of the stone has become disintegrated in places, and, where the slopes are not too steep, it is covered with trees. Otherwise there are bold rock cliffs, which give a most romantic aspect to the valley. The material is apparently rather pervious, for, excepting the water which flows from the springs, there is little evidence of flowing water upon the mountains, although the rainfall is rather heavy, averaging about 59 inches both on the summits and in the valleys. The tops of the mountains are nearly seven thousand feet high, and they have patches of perpetual snow, which, although they do not make much show from below, are of such extent that by melting in summer they swell the volume of the springs at the base of the mountains to from two to four times their winter flow.

The springs apparently have in places a tolerably direct communication with the surface, for a heavy rainfall will increase their flow in from six hours to two days, but the water never presents the slightest turbidity. Its temperature is constant for the whole year at 41° to 44°. The temperature of each spring is entirely constant, but all the springs are not exactly the same. As the mountains are entirely uninhabited, there is no reason to fear the introduction of incompletely purified rainwater. Ordinary rains do not affect the flows. The Kaiserbrunnen, as the largest of the springs is called, was brought to Vienna in 1873 through an aqueduct fifty-five miles long, and having a capacity of 40,000,000 gallons per day. This spring furnished an abundant water supply during the warm months of the year, but was inadequate to meet the growing demand in the winter months, when all the precipitation upon the mountains was in the solid form, and when there were no thaws to increase the flow of the springs. To aid the supply, a series of wells were put down ten years ago upon the line of the aqueduct in the valley of a river which it was thought would add a considerable quantity of water in winter at a time when it was most needed. The supply from this source, however, has been rather disappointing, not exceeding 3,000,000 gallons daily. In the past year other and more distant springs have been connected. The supply at the time of my

visit, July, 1894, 21,000,000 gallons daily, was drawn mainly from the Kaiserbrunnen and from another spring near by, while the water from the higher springs, at least 46,000,000 gallons daily, was all going to waste. The new springs will be required in the winter only when the Kaiserbrunnen is low. The minimum winter yield of the present wells is about 19,000,000 gallons per day. The population of Vienna is 1,500,000; about one half million, however, reside in the recently annexed suburbs, and are not as yet supplied with Vienna water. It is desired to so supply them as soon as a sufficient winter supply can be obtained.

Two projects are under consideration. One of these, which is being investigated by Herr Salbach, contemplates a series of wells in the valley of the Danube in the immediate neighborhood of the city, while Engineer Kinzer, who has constructed the recent additions to the present works, is working upon another spring water project of the same general nature, but drawing from even higher mountains about fifteen miles away in the direction of the Alps. He thinks that the cost of an additional supply of 40,000,000 gallons daily will probably reach $20,000,000. Further supplies could be got from the neighborhood of the present works, but the mill damages are too heavy, and, in addition, it would be necessary to construct a new conduit. The city paid $1,600,000 for mill damages alone on the last addition of 10,000,000 gallons to its supply. The site contemplated in Herr Kinzer's new project is upon government lands and there are no mill privileges. The aqueduct from the Kaiserbrunnen to Vienna has a grade of over ten feet in a mile, and the section above the Kaiserbrunnen for the recent additions has a fall of 1,100 feet in ten miles. The upper part of this is constructed of iron, and the arrangements are very different from those of the conduit built by Mr. Herschel a few years ago for the East Jersey Water Co. The distance is divided into sections, each having a fall of about 100 feet. At the end of each of these sections is a gate-house, and the flow of water through the section is throttled by a gate at the lower end of the pipe, the gate being so regulated as to keep the pipe always full of water. This necessitates the use of very much heavier pipe, as well as the construction of numerous gate-houses which are entirely avoided by Mr. Herschel's design. I was told that it was feared that if the water was allowed to flow freely the upper part of the pipe would be occupied by air, and that the pipe would become corroded and weakened.

Some miles of the conduit lower down were cut out of the solid rock, and, as one rides up the excellent road, which was itself built as an adjunct to the conduit, the only signs of the conduit are the frequent holes in the limestone crags, through which the rock removed was

brought out and dumped into the valley below. The size of these dumps affords the best indication of the magnitude of the enterprise.

Paris has long been supplied, for domestic purposes, with water from springs in several valleys at a great distance from the city. Until about two years ago, the available supply from these sources did not exceed 37,000,000 gallons daily, a quantity which was found inadequate for the two and a half millions of people dependent upon it. For street-washing, for manufacturing and other purposes, the city has an additional supply of water taken unfiltered from the Seine and from a canal, but this water is not ordinarily allowed to be used in the houses. Paris washes its streets instead of sweeping them, and the quantity of water employed for other than domestic purposes is very large, exceeding 80,000,000 gallons daily. For years it was the practice, when the quantity of spring water was inadequate to meet domestic requirements, to supply river water to the wards of the city in regular rotation. Before this was done, however, the inhabitants of the wards were warned of what was coming, and were advised to refrain from using the water for drinking. This condition of affairs was ended in 1892 by the completion of a new aqueduct from springs in the valley of the Avre supplying a maximum of 32,000,000 daily. For twelve miles the aqueduct has a diameter of 5½ feet, and a fall of one in 2,500; for forty-six miles it has a diameter of 6 feet and a fall of one in 3,300; and in addition there are five miles of syphons where two lines of 40-inch pipe are used having a fall of one in 800. The total length of this aqueduct is sixty-three miles and the total fall 132 feet. The walls are 8 inches thick and are built of the natural stone of the country laid in Portland cement. The city is allowed by law to take a quantity of water not exceeding 30,000,000 gallons daily, and an ingenious device at the head of the aqueduct is employed to prevent more than this from being used. The water flows through a submerged orifice at a determined distance below a very long overflow weir, and as soon as the quantity of water reaches the legal limit the excess commences to flow over the weir and back into the river. Below this point and connecting with the aqueduct there is another spring which yields an additional 2,000,000 gallons. The springs supplying the water are scattered through the valley for about two miles above the head of the aqueduct, and are connected with three and a half miles of conduit. They are only a short distance below the surface. The springs, ten in number, were natural springs which formerly discharged over the surface into the river. They have been enlarged, cleaned and deepened, and covered in; the bottoms are made of coarse pieces of flint. The houses covering the springs are 15 to 40 feet in diameter. There are no other springs in the valley. Since the spring water has been collected,

the river bed has been dry and poplar trees are dying for the lack of water. The surrounding country, through which the water probably comes, is rolling and somewhat clayey, the clay containing large quantities of flint. The rock is chalk mixed with flint, while in the valley of the river there is gravel mixed with fragments of flint, all of which is rather porous. The springs are in this gravel, but I could not ascertain its extent. Judging from the topographical map, they may drain the country for fifteen miles back. It is all cultivated land and is occupied by an ordinary farming population. There is no manufacturing. The maximum flow of the springs is about 50 per cent. greater than the minimum, which comes in September. Nearly all of the water comes into the ten springs themselves, but in two or three places the collecting mains going over the minor springs are arranged to allow the entrance of water. Otherwise the mains are water-tight, and the drains built below them to aid in construction are discharged into the river. The aqueduct and the work at the springs cost in all four million dollars. The damage suits for water power and loss of water for irrigation are still pending, but I was told that it was expected that they would probably be settled for about three million dollars, making a total cost of seven millions. One hundred thousand dollars were paid for the springs themselves and the surrounding land. The present minimum of spring water at Paris from all the existing sources is about 53,000,000 gallons daily. This is the only water now taken into private houses. Only a part of the houses have water-closets, but their use is increasing, and thus more water will be required. The present sources are incapable of further development. For the future there are two projects, one for a grand system of filtration of river water; the other for a supply of spring water from the mountains in Haute Marne, 180 miles east of Paris. Studies for these supplies are about to be undertaken; the intention being to secure an additional 67,000,000 gallons daily. The present supplies will prevent the necessity of using unfiltered river water for at least ten years. The suburbs of Paris are all supplied by a private company which is just building an extensive filter plant, and it is proposed to use this in connection with the Anderson Revolving Purifier Process, taking the raw water from the Seine above Paris.

Some of the Dutch cities have a particularly interesting system of collecting water. A large part of Holland consists of land as low as, or lower than, the ocean, and the highest land in the country is a row of dunes, only a few miles wide, extending along the coast from Amsterdam to the Hook of Holland. These dunes consist of fine sand, and the level of the ground is from ten to twenty feet above the ocean. The dunes are entirely uninhabited. The water is collected from this area by a system of open canals. The water in the canals supports a growth of

algæ, and thus becomes unsuitable for use in its raw state. It is therefore filtered.

At Amsterdam about 6,200 acres of dunes are drained by 15 miles of open canals located below the ground water line. The yield of the land is equal to 14 inches of rainfall on the entire area, and the total fall is 28 inches. The entire summer rainfall is believed to be evaporated, and thus lost for water supply, but the bulk of the winter precipitation is utilized. The water, as it comes from the ground in canals, contains iron, but this is all removed by natural processes before the water reaches the filters. During the past year the average supply of water from these sources was six and a half million gallons per day, with a maximum of eight million gallons. Some years ago this supply became inadequate to meet the growing demands of the city, and the water company built, on the other side of the city, another plant, which takes its water from a canal or river not subject to excessive pollution, and the water is carefully filtered. These works, built at a cost of three million dollars, were intended to supply eleven million gallons daily, but the city authorities who wished to secure control of the water works, decided that this water did not meet the sanitary requirements, and that it could not be used for domestic purposes. It is, therefore, at the present time used only for street sprinkling and for other public and manufacturing purposes, about four to five million gallons daily being required. The city insists that the company must provide an additional supply of dune water, the estimated cost of which will be two and a half million dollars, and at the same time declines to authorize the company to increase its capital stock. The object is evidently to put the company in as unfavorable a position as possible, in order that the city may acquire the plant ont favorable terms. The supplies of Leyden and of the Hague are of the same general nature as the dune supply of Amsterdam. It has been suggested that if covered collectors were used instead of open canals for collecting the water, filtration could be omitted and an equally good water could be supplied. On the other hand, it is said that covered collectors become rapidly choked by the extremely fine sand which there exists, and require from time to time to be dug up at great expense. It is also claimed that the water, if so collected, would contain iron, and would require treatment which might be as expensive as the present filtration. For the filtration of this dune water the dune sand itself is used. This is much finer than is elsewhere used for filtration. Its use here is rendered possible by the comparative purity of the raw water.

Brussels, with its two hundred thousand inhabitants, is supplied by ground water drawn from some five miles of collecting conduits in fine sand underneath the forest which also serves as a city park. The drains are generally from 100 to 150 feet below the surface. The possibilities

of the supply from this area are apparently nearly reached. Brussels is desirous of annexing her suburbs and of forming a greater Brussels, with a population of about half a million, and in case this is done an additional water supply must be procured. The city engineers are talking of an extension along the present lines but in new areas, and there is also a project for a supply of filtered water from the river.

The Continental cities are almost invariably supplied with either ground water or filtered river water. The use of impounding reservoirs is practically unknown. Chemnitz and Königsberg have very small reservoirs as auxiliaries to other means of supply, but it is only in England that we find great dams, similar to those so commonly used in America, retaining large volumes of water. Liverpool already derives its water supply from such a source in the Welsh mountains, and Manchester, Bradford and other towns in the north have similar supplies.

Birmingham is just commencing the construction, at an enormous expense, of an aqueduct to Wales, sixty miles away, and there has been talk of a similar supply for London, but in the latter case a royal commission appointed to consider the subject has decided that the present sources can be utilized for many years to come without bad results and at a less expense.

The waters from impounding reservoirs in England are generally filtered, although the watersheds are entirely free from pollution. In this way all trouble from bad tastes and odors due to algæ as well as from temporary turbidity during storms is avoided, and the results are believed to be commensurate with the cost of filtering the water. There are, however, a number of towns, including Manchester, which supply such water without filtration, and Glasgow draws its water from Loch Kathrine without filtration. In Germany, reservoir water is required by law to be filtered whether it is subject to pollution or not.

The following table contains a list of some of the principal European cities, with their populations, the quantities of water supplied daily, in millions of American gallons, and the sources of the water. I have simply included some data which I happen to have, with no attempt at completeness. Most of the statistics are for 1892 or 1893, but those of St. Petersburg and Warsaw are for 1890, and for the English cities, except London, the figures are taken from a local government report for 1887. Most of the figures are calculated from pumping records for an entire year; the statistics for the gravity supplies at Paris and Vienna may be less exact. The Munich and Frankfort supplies are also gravity, but the figures given are calculated from comprehensive weir measurements.

FILTERED RIVER WATER SUPPLIES.

City.	Population supplied.	Million gallons daily.	Gallons daily per head.	Sources.
London, 7 companies,†	5,030,000	190,	38,	Thames and Lea
Berlin, ...	1,606,000	26,	16,	Harvel and Spree
St. Petersburg, ...	960,000	39,	40,	Neva
Hamburg, ...	583,000	32,	53,	Elbe
Warsaw, ...	500,000	6,	12,	Weichsel
Breslau, ...	335,000	7,	22,	Oder
Rotterdam, ...	240,000	13,	54,	Maase (Rhine)
Magdeburg, ...	200,000	5,	24,	Elbe

FILTERED WATER FROM SOURCES OTHER THAN RIVERS.

Amsterdam, ...	515,000	10,	20,	Dune and canal
Liverpool, ...	815,000	22,	27,	Storage reservoir
Bradford, ...	364,000	12,	33,	" "
Dublin, ...	327,000	18,	55,	" "
Birmingham, ...	600,000			" "

GROUND WATER SUPPLIES.

Paris,*	2,500,000	53,	21,	Springs
Vienna, ...	1,000,000	23,	23,	"
Budapest, ...	500,000	22,	44,	Wells by Danube
London (Kent Co.), . .	460,000	16,	35,	Wells in chalk
Leipsic, ...	360,000	5.5	15,	Wells
Munich, ...	300,000	11.5	38,	Springs
Dresden, ...	280,000	6.0	21,	Filter gallery by Elbe
Cologne, ...	255,000	11.5	45,	Wells by Rhine
Frankfort-on-Main . .	186,000	6.7	36,	Wells and springs

UNFILTERED SURFACE WATER SUPPLIES.

Manchester, ...	963,000	24,	24,	Storage reservoir
Sheffield, ...	324,000	—	—	" "
Glasgow, ...	794,000	50,	64,	Loch Kathrine

SIX LARGEST AMERICAN WATER SUPPLIES FOR COMPARISON.—*American W. W. Manual*, 1890.

Chicago, ...	1,099,850	152,	140,	Lake Michigan
Philadelphia, ...	1,046,964	138,	132,	Rivers
New York, ...	1,515,291	121,	79,	Storage reservoir
Brooklyn, ...	776,838	55,	72,	Wells and reservoir
Buffalo, ...	255,664	47,	186,	River
Boston, ...	527,606	42,	80,	Storage reservoir

* In addition, 80,000,000 gallons of river water are daily used for publie and manufacturing purposes.

† Exclusive of ground water.

THE LAKE VYRNWY WATER SUPPLY FOR LIVERPOOL.

By Thomas M. Drown, Member of the Boston Society of Civil Engineers.

(Remarks at the meeting of November 21, 1894, illustrated by photographs.)

The large cities of England must necessarily be dependent, for their ever-increasing water needs, upon drainage areas far distant from those cities, if sparsely settled regions are to be drawn upon.

Glasgow has for thirty-five years enjoyed a pure supply from Loch Kathrine, and Manchester has just completed her aqueduct to Lake Thirlmere, a distance of 96 miles.

The sparsely settled condition of much of the mountainous portion of central Wales makes this region an attractive source for water collection, and two large English cities have availed themselves of suitable valleys in this region. The Liverpool reservoir, in the valley of the Vyrnwy, is now complete, and that of Birmingham, at Rhayader, has just been begun.

Not only are the collecting areas favorable as regards small population, but the rainfall is very heavy, amounting to nearly 70 inches.

I had the pleasure, last summer, of visiting the new Vyrnwy supply of Liverpool, concerning which so much has recently been written. The Vyrnwy was a stream of very variable flow, which, in the dry summer time, did not amount to two million gallons per day, while in the wet seasons there were often destructive freshets. The daming of this valley formed a lake having a superficial area of 1,121 acres, a length of 4¾ miles, and an average width of half a mile. The greatest depth is 84 feet. This lake contains, when full, 13,125,000,000 gallons of water. The area of the gathering ground is 18,000 acres, but the city of Liverpool has the power to divert two neighboring streams, with an additional gathering ground of 5,200 acres. It is estimated that the rainfall on this combined area of 23,200 acres will yield an average daily supply of 53,000,000 gallons, of which 40,000,000 will be available for Liverpool after delivering compensation water as provided by an Act of Parliament.

The compensation water demanded by the Severn Navigation and Fishery Commissioners is 10,000,000 gallons per day. This very liberal compensation was accepted by the Liverpool Corporation. But, much to their surprise, Parliament, while the bill was before it, imposed very unexpectedly an additional compensation of over 1,200,000,000 gallons a year in "freshets" of 40,000,000 gallons each, whenever the Severn Commissioners may require. These "freshets," which are a very severe

drain upon the reservoir, and which involved the raising of the dam five feet higher than was originally intended, are supposed to be beneficial in connection with the breeding of fish and the scouring of the Severn.

The following are the principal dimensions of the dam:

Total length along the top, 1,165 feet.

Height from the lowest part of the foundation to parapet of carriage way, 161 feet.

Height from river bed to sill of overflow [under the roadway], 84 feet.

Greatest thickness at base, 120 feet.

Width of roadway over top of dam [between the parapets], 19 feet 10 inches.

Batter, or slope, of the wall on the front, or water side, 1 in $7\frac{1}{4}$.

Slope of back of wall, 1 in $1\frac{1}{2}$.

Total quantity of masonry in the dam, 260,975 cubic yards.

Total weight of the masonry, 510,000 tons.

Quantity of earth and stones, excavated for the foundation, 220,890 cubic yards.

Refilling at the front and back of the wall, 79,501 cubic yards.

The cost of the masonry was £530,000, and the total cost of the dam, £601,500.

A fine new road, nearly 12 miles in length, including the beautiful viaduct over the dam, completely encircles the lake; it is from 20 to 30 feet in width.

Nothing was removed from the valley before flooding except trees or lumber and stone which had value. There was no attempt to remove vegetation or soil. With us in Massachusetts, such neglect to remove organic matter would have resulted in very foul water, but there has been no inconvenience from this source as yet, as I was informed by Mr. Parry, the water engineer of Liverpool. The lake was stocked with trout from Loch Leven, and during the first year they grew to enormous size, making the lake a favorite resort for fishermen. The fishing is said to be still good, although the trout are not as large as they were when they had the abundance of food afforded them during the first year.

One reason why the water does not become foul may be that the compensation water, which is drawn off near the bottom of the reservoir, to some extent prevents stagnation. It is true that, during the first year, the bottom water was discolored and had a bad odor, but this condition of affairs, according to Mr. Parry's statement, does not now exist. Moreover, there is not that great difference in the temperature between the water at the surface and that at the bottom which there is here during the summer. I could not learn that anywhere in England is the organic matter removed from the bottoms and sides of valleys before flooding for reservoirs, or that any bad consequences result from this neglect. If this is the case, the immunity from trouble must be due to the prevalence of a lower average summer temperature.

The straining tower, situated about three quarters of a mile from the

dam, is an ornamental structure standing in 50 feet of water and 104 feet above the surface, and 30 feet in diameter. It forms the entrance to the aqueduct. Two columns of pipes, 3 feet 6 inches in diameter, outside the tower, are so arranged that water can be drawn from any level of the lake. The water is strained through a cylindrical screen of fine copper wire [gauge 14,400 meshes to the square inch] 9 feet in diameter and 25 feet high. When the screens are clogged, a bell on the tower is rung automatically, calling the attendant to clean them. The screens are lifted into the body of the tower and are there washed by jets of water supplied by a special reservoir on the hillside.

The aqueduct is nearly 69 miles long, and, with the exception of four miles of tunneling, consists of cast-iron pipes from 39 to 42½ inches internal diameter. Eventually there will be three pipe lines to Liverpool, each with a capacity of 13,500,000 gallons a day.

At Oswestry, about 19 miles from Lake Vyrnwy, are situated the filter beds. At present there are three filters, with a total area of 24,000 square yards. The filtration is conducted according to the usual English system. The filters are scraped when the loss of head is from 12 to 18 inches. The lake water is brown in color, and about half of the color is removed by the filters.

A mechanical analysis, by Mr. Hazen's system, of a sample of the sand used in these filters, showed that 10 per cent. of it was finer than 0.3 of a millimeter, and indicated a maximum filtration rate of 60,000,000 to 70,000,000 gallons.* At the time of my visit in June last, No. 1 filter, having an area of 1.65 acres, had passed 171,000,000 imperial gallons between scrapings.

The Liverpool water works, which include also reservoirs and filter beds at Rivington, with a capacity of 12,000,000 gallons a day, and wells in the New Red Sandstone yielding 6,500,000 gallons a day, are all under the charge of Mr. Joseph Parry, water engineer, to whose courtesy I am indebted for my information concerning these works.

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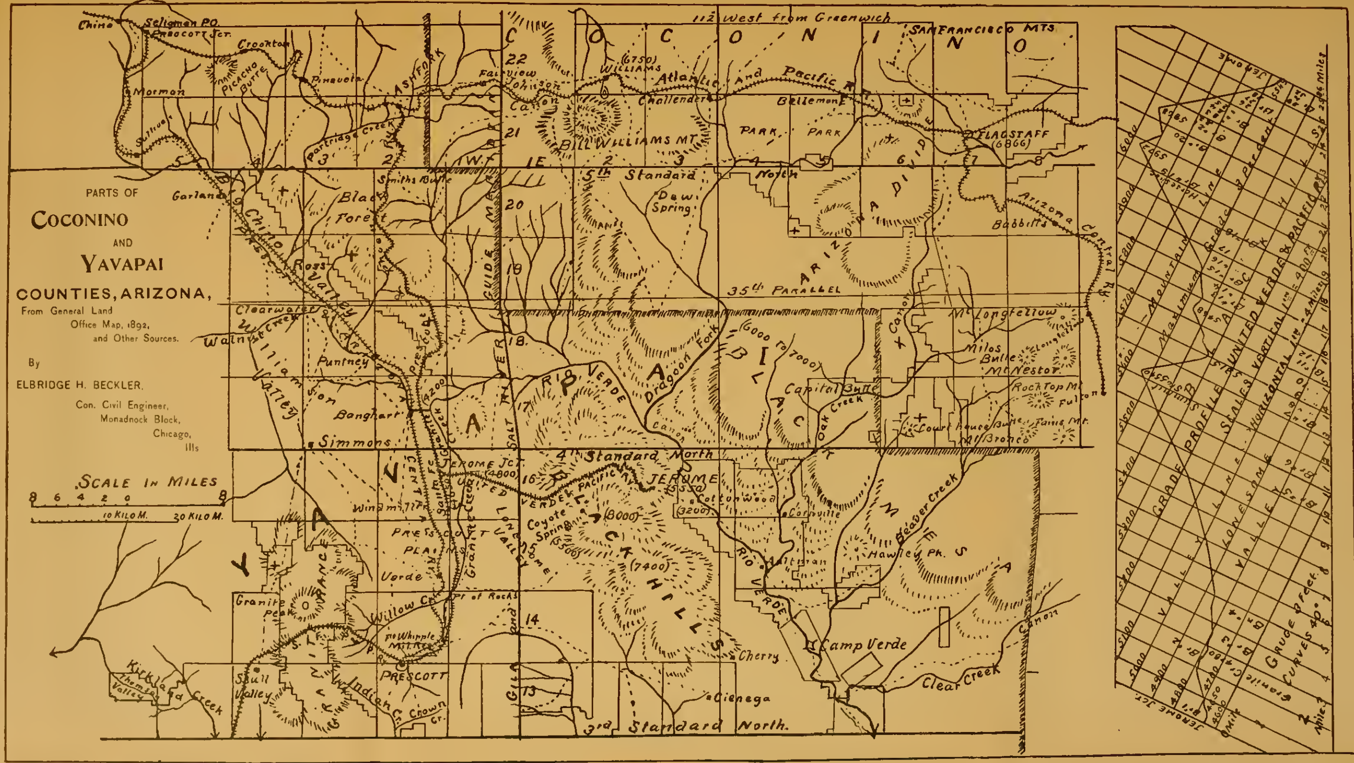
* See "Some Physical Properties of Sands and Gravels, with Special Reference to their Use in Filtration." By Allen Hazen, Mass. State Board of Health; Twenty-Fourth Annual Report, 1892.


MAP SHOWING PORTION OF THE
UNITED VERDE & PACIFIC RY.
YAVAPAI COUNTY, ARIZONA,
JEROME TO SUMMIT.
13.66 Miles
Constructed 1894
E. H. BECKLER, Engineer
Monadnock Block,
Chicago,
Ills.
Parenthetical Figures Denote Elevations Above Sea Level
Projected Position of Section Corners T.16N.R2E
JEROME.
UNITED VERDE COPPER COMPANY'S WORKS
Foss & McDonell Camp 2
Foss & McDonell Camp 1
Pinone Grove
Hurley's Cut
Horse shoe Siding
Lowry's Knob
Porter's Bridge Camp
Campbell's 2
Campbell's 3
Summit
Sectionhouse
Supply Store
Powder
Elevation About 8000
MINGUS MOUNTAIN
Section Lines Projected
Scale of Feet
Metres
Recurrent Spring
Tunnel
Trail
Grave
(6300)
(6400)
(6100)
(5490)
(5460)
(5313)
(5640)
(7000)
(5972)
(5920)
(5723)
(5549)
(6500)


PARTS OF
COCONINO
AND
YAVAPAI
COUNTIES, ARIZONA,
From General Land
Office Map, 1892,
and Other Sources.
By
ELBRIDGE H. BECKLER.
Con. Civil Engineer,
Monadnock Block,
Chicago,
Ills
SCALE IN MILES
8 6 4 2 0 8
10 KILO M. 30 KILO M.
112 West from Greenwich
Atlantic And Pacific R.R.
Flagstaff (6866)
Williams (6750)
Bill Williams Mt.
5th Standard North
35th Parallel
4th Standard North
3rd Standard North
Jerome Jct. (4800)
United Verde Pacific Ry.
Jerome (5550)
Prescott
Camp Verde
Rio Verde
Clear Creek
Beaver Creek
Granite Peak
Seligman P.O.
Prescott Jct.
Chino
PROFILE
Scales, Horizontal 1 in. = 4 Miles, Vertical 1 in. = 400 Ft.
United Verde & Pacific
Mountain
Maximum Grade
Jerome Jct.
Jerome
Grade 4%
Curves 40°
Lonesome Valley
Granite Creek

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THE UNITED VERDE AND PACIFIC RAILWAY.

By Elbridge H. Beckler, Member of the Montana Society of Civil Engineers.

[Read February 9, 1895.]

The subject of this paper is situated a little easterly from the centre of Yavapai County, Arizona, twenty to thirty miles northeasterly from the town of Prescott. It is a three-feet gauge railway, twenty-six miles in length, and lies along the easterly and northerly slopes of the Black Hills of Arizona, and extends westerly from these hills about ten miles, the termini being, at the east, the United Verde Copper Company's works at the town of Jerome; and at the west, Jerome Junction, a connection with the Santa Fé, Prescott and Phoenix Railway.

Personal capital for private use in transporting the product, and furnishing supplies for the operation of the United Verde Copper Company's mines, properties owned principally by Mr. W. A. Clark, of Butte, Montana, brought this railway into existence. The road performs the usual duties of common carriers, having duly qualified by incorporation, complying with United States and Territorial laws, accepting the conditions, restrictions and limitations, and receiving the usual benefits, of roads constructed for public use and convenience and dependent upon such use for the return of its operating expenses and interest on capital invested. While the public use helps slightly, it is a trifling matter, and had no influence in the origin, development or perfection of the enterprise.

The conditions which made it desirable to construct this road; the character of road which could be constructed so as to be profitable —that is, furnish cheaper transportation than by other means; the principles which should govern in making an economical location, as regards details of construction, are some of the questions which would present themselves to an engineer called upon to investigate the situation. A few facts bearing upon these matters will be mentioned before entering upon the description of the road and the details of construction, that those who read may judge of the fitness of the work.

Reference to a map of Arizona shows the Black Hills a disconnected group of mountains lying in latitude 34° to 35° and longitude 111° 45′ to 112° 15′, covering an area of ten by thirty miles, and with the major axis bearing 30° west of north. The Verde River heads northwest of these hills, with some of its southern tributaries rising in the Granite Range, from which the water flows northward along the

west side of the hills to the junction with the main river. The river then passes by the north end of the mountains and flows southerly by the east side. In this way the Verde and its tributaries almost completely encircle the group of mountains.

The United Verde Copper Company's mines are located on the northeasterly side of the mountains, overlooking the Verde River, from which they are distant about three miles. The mines are at an elevation of 5,500 feet above sea level; the river at this point is 3,200 feet above sea level, and the top of the mountain about 8,00 feet. The top of the mountain is covered with a fairly good quality of pine timber; that within a few miles of the works has now mostly been cut in supplying wood and mining timbers, and lumber for buildings.

East and north of the river the country rises abruptly to an elevated plateau (elevation between 6,000 and 7,000 feet) of extensive area, reaching northerly beyond the Atlantic and Pacific Railroad to the breaks of the Grand Cañon of the Colorado. There are large bodies of pine timber on this plateau. West of the Black Hills are the valleys of these southern tributaries of the Verde, which flow northerly, the principal one being Granite Creek. The bed of the stream is ten miles from the foot-hills, a long, gentle slope covering this distance, starting at the foot-hills with an elevation of 5,200 to 5,500 feet, and descending to about 4,800 feet, opposite the north end of the mountain, at the creek, and 4,200 feet at the junction with the Verde River. The Santa Fé, Prescott & Phoenix Railway comes into this Granite Creek depression at about the nearest point to the mountain, and about seventeen and a half miles from Jerome, by air line.

From Jerome a wagon road climbs over the mountain, through a pass about 7,000 feet high, and, after reaching the foot-hills on the westerly side, divides, with one branch extending to Prescott and another to Massick's Station. A wagon road also extends down into the Verde valley from Jerome, making a descent of 2,500 feet in about four miles.

The early workings of the mine consisted of making an open excavation in the mountain side, where a large body of red oxide copper ore, rich also in gold and silver, was exposed on the surface. It has been stated that several millions of dollars were shoveled up and hauled away before any attempt was made to find and follow the mineral vein. A large sum of money was spent in constructing a wagon road to the A. & P. R. R. at Ash Fork, then the nearest or most practicable outlet to rail transportation. Lack of experience and reckless expenditures caused the failure of the parties owning the property, after their surface riches began to diminish.

When Mr. W. A. Clark purchased the property, development was

begun in earnest. The obstacle in the way of demonstrating the great value of the property was the expensive wagon haul. The best outlet was over the mountain road to the Prescott and Arizona Central Railway, twenty-five miles to the point where Massick Station now is. The Prescott & Arizona Central Railway went out of business in 1893, when the Santa Fé, Prescott & Phœnix Railway was constructed through the same section of country. This wagon road had two hills to pass over in each direction, with a rise of about 1,500 feet in each place. The grades on these hills in some places reached 16 per cent., and for long distances exceeded 12 per cent. The heavy teaming made it necessary to keep quite a force on the road, at all times, to keep it in repair. The soil on the mountain, where there was any, and also in the valley west of the mountain, is of a peculiar nature. A little rain or snow changes it into a lively mixture resembling quicksand. Horses sink into it to the fetlock, and lightly loaded wagons settle down to the hubs. In good weather, with good roads, a freight team could make a round trip a week. After a few days of showery weather the road became practically impassable.

Owing to the nature of the road, it has been necessary to shut down all work of producing from the middle of November to the middle of April each year, working the mine but eight months, although quite a force would be kept through the winter, making developments and doing other necessary work on the property. It was the aim to have supplies, and everything necessary for hibernating, prepared before the roads became bad, but invariably the matter was put off a little too long, and the last shipments, in and out, were attended with great expense and difficulties. An annual rainy spell in July and August always made the road useless for from one to three weeks. The value of the property has been much affected by the necessary closing down of four months each year.

There were several attempts to introduce tramways and inclined railways to pass over the mountain. Several surveys for different schemes were made, and enough work was done to leave marks which are still visible in various places. In 1891 the Link Belt Engineering Company undertook to put in a cable tramway over the mountain, from the works to the west side, to deliver and receive freight at the foot of the westerly hill, from which point there was a comparatively easy wagon road to the railroad, twelve miles away. A branch railway, or spur, was also planned to connect with the tramway. The system proposed consisted of towers, or posts, every 20 feet, carrying two rails on a cross-arm. Travelers, to which were suspended buckets, boxes and hooks for the carriage of matte, coke, wood, etc., were placed on the rails every 100 feet and connected by cables. The cable passed around a drum or

wheel at the ends, and wherever an angle was necessary, and at the power house.

The company built the tramway but could not make it work. It was proposed to handle five miles of tramway from a single power station. There were many changes of grade, dipping down sharply into valleys, and rising abruptly over sharp ridges, in the attempt to get a short direct line. There were some angles where it was necessary to change direction. When power was applied to the cable, the wire, with the traveler and buckets, was lifted from the towers and track, crossing the valleys. There was then a great strain on the cable and supports at the summits, and at the angles. After working on the tramway until the spring of 1894, two and a half miles were made to operate by putting in two power stations, in this distance, and by relieving the more abrupt changes of grade and alignment.

During the working season of 1894, all the product of the mine was taken out over the tramway, and coke was taken in. Some wood, cut on the top of the mountain, was taken in by the same way in the last two months. On account of the difficulty in making roads on the steep and rocky slopes of the mountain, all this wood used at the works in smelting, and in several hundred pits of the open air roasts, has been packed from the mountain top on the backs of burros. Nearly all that was convenient to the works has been cut in order to keep up the supply of twenty cords a day, until now there is scarcely any within a distance of four miles.

It was becoming urgent to have some other means of getting wood, or other fuel. In addition to the wood, the furnaces consumed daily about thirty tons of coke. The coke and other supplies, and machinery, gave about as great a tonnage towards the works as the product, in matte and bullion, gave in the other direction. The plant had grown rapidly by frequent additions, until the daily capacity of the works was about sixty tons of matte and bullion.

Several surveys for a railroad to get out to other railroads had been made. The difficulty of reaching the place, going around, or over, so steep a mountain, the expensive construction, and the uncertainty of future traffic, made railroad companies hold off. The mine is now opened to a depth of five hundred feet, and ore has been taken out to a depth of less than three hundred feet. In the winter of 1893 Mr. Clark decided to construct the railway at his own expense.

At this time it would be fair to assume that the daily traffic to and from the works was about one hundred tons, handled at a cost of eight dollars per ton, not including twenty cords of wood at five dollars per cord, with this latter item becoming rapidly more expensive. The plant had probably cost more than $1,000,000. No other mines have been discovered in that immediate vicinity.

With the foregoing facts, or conditions, the question for decision was, what kind of a railroad should be constructed.

The problem for solution was, in some respects, easier than the location of a road for public use, dependent upon general traffic. As seen above, the wagon haul was costing eight dollars per ton. A portion of the tramway becoming useful (after it was decided to build a railway) probably reduced this cost to five dollars per ton. The exact cost of the tramway may never be known. It was not far from $70,000, but, as it is not yet decided who had to stand this expense, on account of its failure, the cost is left out. Five dollars per ton would maintain a tramway and transport the metal, and coke or coal, over the tramway and wagon road. Machinery and other bulky articles would still require the use of wagons the entire distance. The construction of the balance of the tramway, and the short and cheap railroad spur, might further reduce the working cost to four dollars per ton. It will readily be seen that there was little danger of making the road unprofitable by reason of excessive cost, when there was a possible limit of four dollars per ton to be expended in operating expenses, maintenance, and interest charge, in transporting one hundred tons daily a distance of twenty-six miles. A few figures will show that one dollar per ton, or one hundred dollars per day, would be sufficient for maintenance and operating, which would leave three dollars per ton, or three hundred dollars per day, for interest charge. This sum, capitalized at 6 per cent., shows that over $50,000 per mile could be spent in construction and equipment.

This might be a proper way to figure if the railroad was to be built for perpetuity, with a growing traffic, by reason of a greater development of the country. The life of the mine is unknown; in ten years it might be abandoned; or, by reason of the discovery of other mines in that section, a more extensive smelting plant would be more favorably situated at some other point. A great increase of traffic might require such a change in service that a road constructed for present needs would be entirely unsuitable for the work, and the necessary changes would be equal to the construction of a new line. It would be unreasonable to construct and equip a first-class road for twenty daily trains while the present business would require but one train.

In view of these conditions it would be fair to assume that the price per ton should contemplate the refunding of the capital expended, in a period of twelve years, as the probable time when the proposed road would reach the end of its usefulness. Figures show that four dollars per ton would provide for maintenance, operation, interest on capital, and refunding of capital in twelve years, with a construction cost of $35,000 per mile. This demonstrates that there was no danger of exceeding the safe limit.

In the further consideration of what would be a justifiable expenditure for the traffic it became evident that there was no occasion to approach very near the cost of wagon, or tramway, rates, but it was not desired to carry economy in construction to a point out of proportion with economy in operation.

The number of daily trains is a factor affecting cost of transportation and of maintenance, and thus influencing the question of location. The minimum train service is, of course, one full crew, and in this case it was desirable to so proportion the engines and grades to the traffic that one crew should be able to do the daily work, and with one trip per day, if possible, although the mileage (twenty-six miles) would not prohibit two trips if necessary.

The question of gauge for such a road is an important one. Able writers, and engineers, have in the past discussed this question in its application to all railroads. The question here, where there was a connection with another railroad at one end only, is not so broad.

Many of the arguments for and against a three-foot gauge, as compared with the standard 4 feet $8\frac{1}{2}$ inches, are not capable of expression in money value. We find, for narrow gauge, cheaper construction by reason of using sharper curves on a mountain side, reducing heavy cuts and high, expensive bridges, crossing chasms ; narrower roadbed ; lighter bridges, and lighter rails, ties and fastenings. There would probably be not much difference in the cost of equipment, as the smaller number of cars required for standard gauge road would nearly offset the difference in cost. By using principally cars of other roads, the standard gauge equipment could be made to cost less than the other. The engines, to perform the same service, might cost 20 per cent. more on the standard gauge road, but it would probably be economical to purchase engines capable of doing 50 per cent. more work, at an increase of cost of 30 per cent.

Maintenance of the narrow gauge is more expensive by reason of the greater amount of curvature, but less expensive on account of the lighter track material and lighter rolling stock. On the whole, maintenance expense is probably less on the narrow gauge.

Transferring from the cars of one gauge to the other does not make much additional expense, especially with traffic of such a nature as is found in this case. The incoming material is principally coal and coke, loaded in box, stock, or gondola cars, from which it is necessary to shovel it. By unloading these cars into bins, from which the coal and coke can be drawn out below, into narrow gauge cars, which can be unloaded by drop bottoms and side gates, there is scarcely any more handling than if the broad gauge cars delivered the material at the destination. There is an additional expense in switching.

The outgoing product, metal and bullion, has to be handled once extra, but this is in such shape (in sacks) that it can be very cheaply transferred by trucking from car to car.

The use of foreign cars on such a short road would show a car mileage balance against the road at all times. The few cars owned by the road would be away from home, widely scattered, and probably standing on side tracks, earning no mileage (unless the per diem system came into practice) nine-tenths of the time. By using broad gauge and foreign cars the car repairing account would be largely increased. The old cars of other roads are always finding their way to small roads, in out-of-the-way places, where they undergo repairs before returning home.

The clerical force for the short narrow gauge road is rendered much less by dispensing with all the help usually employed in the car accountant's office.

As it was possible to do the required daily work with one crew on either gauge there would be no material difference in cost of train service.

While no careful location for a standard gauge road was made, sufficient data were obtained to show that the cost of roadbed, bridges and track material would be increased not less than 80 per cent., or reduced to the cost of hauling the traffic, would add an interest charge equivalent to twenty cents per ton.

There was little choice as to route. The works being situated 2,300 feet in elevation above the Verde River, any practicable grade making the descent would be developed so far westerly around the mountain that the only proper thing to do would be to connect with the existing road near at hand, although there were many reasons for desiring a connection directly with the Atlantic and Pacific Railway, without the intermediate line of the Santa Fé, Prescott and Phœnix Railway.

The junction point was selected at a place where water could be obtained, the line being lengthened about 3,000 feet for this purpose. Water is scarce in Arizona, and there are long stretches where none can be found. With no water along this line it was quite necessary to have a water station at each end.

The difference in elevation between the termini is about nine hundred feet. It would have been possible to make a descending grade from the mine to a point on the Santa Fé, Prescott and Phœnix Railway, by passing around the mountain with a great loss of distance.

The mountain sides are cut by great ravines occurring frequently, with only sharp ridges between, which extend for a mile or more, without much change of elevation in the crest. To pass around one of these ridges from one gulch or chasm to the next would require a detour of

over a mile to advance less than one fourth the distance. There appeared to be less difficulty in crossing these ridges near the point where they started out from the main body of the mountain, or through some saddles or depressions in the spurs, not far distant from such point.

The selection of these places to give the shortest line and cheapest construction gave some undulations to the grade not otherwise necessary. This also influenced to some extent the selection of the maximum grade. There were two such spurs in the first three and a half miles next Jerome, where any lighter grade would have added materially to the length of the line. A level or descending grade, out of Jerome, would have carried the line several miles northward to pass around projecting spurs. So long as the maximum grade was kept down so as not to affect the handling of the daily business with one train, this feature was not considered very objectionable.

The selection of the engine for the work was made with the probable grade in view. The sharp curvature to be used demanded that the rigid wheel-base of engine should be as short as practicable. The attempt was made to adjust these factors of grade and curvature, affecting train capacity and construction cost, to the weight and class of engine so as to produce the most economical condition in operation.

A Mogul engine, with 9 feet rigid wheel-base, was able to do the work on a 3 per cent. grade, and could be made to pass over curves of 100 feet radius. For greater ease and comfort the limiting radius was made 146 feet, except in one instance, where 162° were turned with 130 feet radius. This sharp curvature was needed in crossing the ridges without excessive cutting or tunnels; in crossing the gulches without very high bridges, and in placing the line closely on the sidehills to make a roadbed chiefly in cutting, for greater permanence, or where the steepness of the hillsides prohibited the building of embankments. For fully one-half the distance of the 13.66 miles on the mountain the natural slopes were not flatter than 2 to 1, and for the balance there were few places where it was flatter than 3 to 1. Using 40° curves gave cutting at the crossing of ridges from 10 to 25 feet in depth (in one cut 48 feet). The crossing of gulches with similar curves gave bridges from 25 to 48 feet in height. The excavations on the mountainous portions amounted to 110,000 cubic yards, against 150,000 cubic yards embankment with practically no waste excavation, with a 300 feet haul, while the comparative lengths of cut and fill on center line, for the full distance, are 47,430 cut to 20,500 fill, omitting 3,350 lineal feet in bridges.

This gives an idea of the steepness of the slopes encountered.

The maintenance of roadbed is an important matter, and, in that

section of country, this would be attended with much less expense, with the light train service, where the track rested upon original ground in an excavation, than where high, or side-hill, embankments were made. Some additional curvature was used in so constructing the road as to avoid borrowing for fills.

The grading in the valley amounted to 4,000 cubic yards per mile, exclusive of terminal grounds. The roadbed here was principally in embankment. On the mountain, the work averaged per mile: earth excavation, 500 cubic yards; loose rock, 2,000 cubic yards; solid rock, 5,500 cubic yards; ballast (in the excavation only), 1,000 cubic yards; and borrow, 1,000 cubic yards, making a total of about 10,000 cubic yards per mile.

The location of line was begun May 14, 1894. The mountainous portion of the line (13.66 miles) consumed the time of a party of eleven men about seven weeks, making a progress of about one-third of a mile per day. The alignment gives an average of 727° of angle per mile (2 full circles), and the average length of tangent is 166 feet. There was no preliminary line, except that run from day to day by the location party. There was no water near the line, except at the ends. There is a spring four miles south of line on the west side of the mountain. This made the extreme haul of water eleven miles. During the survey, the camp supplies and water were packed on burros. The difficulties of transportation, and even of walking, can be understood by the statement of a member of the party, made one Sunday afternoon. He said "We have had no water since yesterday at 4 o'clock." The distance from the camp to Jerome, where there was plenty of water, was only four and a half miles by trail, and the party did not work Sunday. It cost $5 a day to pack water and supplies to this camping ground for the engineering party.

The maximum grade (3 per cent.) was equated for curvature at the rate of 0.03 foot per degree. As the curves were very frequent, with short tangents between, often less than one hundred feet, the compensation for curvature was distributed so as not to make changes of grade for distances less than three hundred feet. It is impracticable on any road to have grade changes maintained at the precise ends of curves, and it is better, in all cases, where tangents are short, to limit the changing points to not less than five hundred feet, using an average grade extending over curve and tangent, which will allow the proper amount of compensation.

No reverse curves were allowed, the minimum tangent being fixed at 60 feet. This might better have been made 100 feet. It would probably have been better to have made this limit 150 feet, or even 200, as in most cases the lateral movement of the center of the curve of 100

feet length, in doubling its length, does not add very much to the cost of work, and the character of the alignment of road is much improved by not having changes of direction made too abruptly.

Examination of the map of the line will show a place where it would appear to be desirable to construct a tunnel, and where 400 feet of tunnel, with not very heavy approaches, would shorten the line 4,700 feet. Seven thousand dollars were spent in grading the longer line around the hill. The tunnel would probably have required a timber lining, and the cost of timber would have been great. All supplies, powder and water would have had to be packed to the work, or an expensive wagon road would have had to be constructed. The difference in cost, now, with the railway in operation, will justify the spending of the $70,000 for a temporary line.

When construction was begun, a wagon road was built along the westerly portion of the mountain work. On the easterly end, burros were used for packing all supplies, powder, tools and water.

The grading was begun the 23d of May. The scarcity and expense of water for stock, the difficulty of getting cars and track, or carts, made it best to use wheelbarrows as much as possible in moving the material from cuts to fills. A few mining cars, pushed by men on light tee rail, were used on the east end, and eight carts were in service on the westerly end in making the longer hauls. Débris can be wheeled but a short distance with profit at the usual prices. It was also found that it cost more to handle carts in the narrow cuts and on narrow banks, than is usual on broad gauge roadbed.

The work of grading was mostly done by contract, the railway company furnishing all supplies and tools for purchase by the contractor. The amount of work given to any party was based on the engineer's judgment of the ability to handle; in some places a single cut being let to a gang in partnership for that piece of work only. The cost of hauling water eleven miles was found to be four cents per gallon, and five gallons per day per man was about the amount required.

Packing on burros cost five cents a gallon for four miles; this sum probably gave some profits to the packer, who drove eight burros, each loaded with twenty gallons.

The roadbed was made twelve feet wide at grade in cuts, and twelve feet wide on top of embankments. Excavations were made one-half foot below grade for ballast, The material being mostly rock, making fair ballasting material, six inches of the broken stone were put in by the grading contractors preparing the surface for the ties. The roadbed was brought into excellent surface, the engineers setting grade pegs every twenty-five feet, generally, giving the proper elevation for curves. The fine condition of roadbed was a great help in track-laying,

as it would have been almost impossible to use any track until surfaced, on account of the numerous sharp curves, if the roadbed had been rough.

The grading was prosecuted so that tracklaying could begin at the the west, and not be delayed for roadbed.

Nearly all the material for bridges had to be taken to the bridge sites by team, or had to be hauled ahead by wagons on the grade. There was very little opportunity to haul ahead on the grade, as there was seldom a half mile without a bridge, and it was not practicable to get across the gulches with wagons loaded with timber. It would have added largely to the expense to attempt to construct bridges far ahead of the rails.

The bridges were mostly trestle bents on subsills, with spans of nearly sixteen feet, excepting at a few places, where piles could be driven. The pile bridge had three piles to the bent, with 14-feet spans. The trestle bents had four posts (two batter and two plumb) under a ten-foot cap of 12 by 12 timber. There were six stringers, 7 by 16 to the span. Bridge ties were 6 by 8, 12 feet long, spaced 15 inches centers, and a guard rail 5 by 8 was dapped down on the ends of the ties. The posts were of round timber, standing on flattened sills.

The round timber was procured on the Mesa, on top of the mountain, and was run down to the line in slides, where it was impracticable to construct a cheap wagon road. It was necessary to load most of it on cars, to be hauled forward as the track progressed. The heights for trestles were determined in advance, so that all framing of posts and sills was done before loading on cars. The most of the bridges were on curves and the elevation was framed in the posts. The subsills were cross ties cut in two pieces, as the price of ties was no greater than other timber. They were more convenient for handling, and gave the liberty of using a greater or lesser number of pieces under each bent, depending upon the nature of the foundation. Generally, twelve pieces were sufficient for each bent. Sawed timber was furnished by sawmills located at Williams, on the Atlantic & Pacific Railroad, about sixty-five miles distant.

The bridges were built by contract at a price per thousand feet B. M., the railway company furnishing the material. The foundations were prepared by day force working for the railway company, and were always ready in advance of the bridge crew.

A sufficient crew was kept erecting bridges to enable the structure to be set up with the least possible delay for all parties. That is, it was planned to have each structure ready for crossing as soon as the track to that point had been surfaced, one crew being used for both tracklaying and surfacing. The bridge crew would finish up all bracing,

spiking and placing of guard rails while the track would be advancing to the next structure. There was not a day of idle time for either force during the construction of twenty-six bridges and the laying of thirteen miles of track.

Track-laying was begun on the 13th of August. Across the open country, twelve miles at the west end, rails were laid from an iron car, and ties were distributed with teams. On the mountain, teams could not be used while the track-laying was progressing, as it was not possible to get on or off the grade except at a few places. The bridge sites (gulches) prevented hauling ahead while the bridge was being built. The frequency of the bridges prevented working nights, as generally but one day's laying could be made ready at a time. Hence the idle time of the teams would have added to the expense.

It was found best to use a car similar to the iron car, on which about 125 ties could be piled on two rails. A heavy wagon and team of horses were placed on the grade just ahead of the rails, and the ties were thrown on the wagon, hauled ahead and distributed to half tie the track, while the iron and tie cars went back for other loads. The balance of the ties were placed under the rails by a crew working just ahead of the spikers. This method worked better with the light, short ties, 6 by 7, 6 feet long, than it would with heavier ties on a broad gauge road. It was not practicable to use any of the track-laying machines, with side carriers for rails and ties, where the curves were so sharp.

The track force consisted generally of fifty men, divided as follows: A superintendent, 8 iron men, 4 strappers, 1 peddler, 10 spikers, 5 nippers, 2 tie-spacers, 4 tampers, 3 drivers and 12 tie-buckers.

This gang could generally lay a half mile in half a day, and the amount of material was about a train load. The other half of the day would be spent in surfacing and filling track while another train load was being brought forward. Where the distance between bridges was more than half a mile, sufficient material would be brought to the front to permit the track-laying to continue to the bridge site before the surfacing was done. In surfacing and filling track across the twelve miles of valley work, teams and scrapers were used. Material was scraped from the borrow pits, thereby preventing the robbing of embankments. This made the work quite economical. The teams could not be worked to advantage in cuts, nor where embankments were more than three feet high. Eight teams could fill a mile per day.

The rails were rolled at the Colorado Fuel and Iron Company's Works, Pueblo, Colorado, 45-pound steel being used on the mountain and 40-pound section on the valley work. The 45-pound section was the Denver and Rio Grande Railroad pattern, with sloping sides to the

head. The 40-pound section was practically the American Society of Civil Engineers' section, with vertical sides on the head. Angle bars 24 inches long, with four holes, were used for suspended joints. The same bar fitted either pattern of rail. The switch material was all designed for the 40-pound section, the yards being laid with that rail, to avoid confusion. The switch stand was the Banner pony stand.

Rail braces were used on all curves, five to the rail on the outside of curve only. The brace was the Colorado Fuel and Iron Company's wrought brace, which takes two spikes, and fits closely under the head.

Guard rails were placed on the inside of the inner rail, on all curves of 30° or over. This guard rail was of the 40-pound section, and was placed close enough to the track rail to let the flange of the wheel press against it, before it would permit the flange of the outer wheel to crowd very hard against the outer rail. It was found necessary to put rail braces against this guard rail, to prevent its being overturned, thus showing that it was quite effective in preventing the wheels from crowding or climbing over the outer rail.

It might have been possible to save the expense of guard rails on curves of 30° or a little more. The guard rail is an extra precaution against derailments; and on such steep mountain sides an accident might be attended with great damage to property and possible loss of life. It might be advisable to economize in the use of guard rails by taking care, in location of such lines, to make a limit of about 24° for curves without guard rails, taking slightly heavier work, and then using only curves approaching the sharpest, or maximum, curve permissible at all places requiring sharper than 24°.. There is a natural tendency, however, for a locating engineer to use the curve that, according to his judgment, fits the place, regardless of such consideration.

There were no derailments on any sharp curves during the time the road was operated by the construction forces. The rails were all curved at the material yard at the junction before moving to the front. The foreman was supplied with the alignment table showing the number of curved and straight rails required for the track, and rails were sent forward exactly as needed. The curves were numbered from the beginning, and the rails for each curve were marked in paint with the number and degree of curve. Rails were laid with broken joints, and 28-foot rails were put in as needed, to keep the joints nearly at the center of opposite rails. Seventeen ties to the 30-foot rail were used on curves, and fifteen ties to the rail on tangents.

At the junction with the Santa Fé, Prescott and Phœnix Railway there were constructed coal and coke bins, with elevated tracks, for the broad-gauge cars to be run upon, for unloading into bins, from which the narrow-gauge cars can be loaded below. These bins have a capacity

of 150 tons of coal and 200 tons of coke. The bins consumed about 150,000 feet of timber for construction.

A warehouse and long platform were constructed for the transfer of freight in car lots, the side tracks of the two roads being on opposite sides. A joint station building was provided for the transfer of passengers, baggage and express and the small lots of freight. Section house for trackmen was built at a convenient point. At Jerome there is an engine house and turn-table, and a two-story passenger and freight depot, with office in the second story. There are coal and coke bins, elevated, so that the fuel is delivered conveniently for use in the furnaces and power-house.

The machine shop and foundry used with smelting works furnish all necessary means for repairs, and usual work on engine and cars. This whole plant being so far from the centers where machinery and supplies can be procured, it has been necessary to have quite expensive shops.

There are water tanks, with 23,000 gallons capacity, at the ends of the line, and it is worth noting that an engine tank of water (2,000 gallons) taken at the junction will take a train to Jerome, doing eighteen miles of work.

Tracks are provided at the junction for the transfer of freight directly from car to car.

The road has two Baldwin compound Mogul engines, of which some of the features are: two cylinders, 10 inches in diameter; two cylinders of 17 inches; stroke, 20 inches; drivers, 41 inches diameter; driving wheel base, 9 feet; engine wheel base, 15 feet 5 inches; weight on drivers, 60,000 pounds; engine in working order, 70,000 pounds; capacity of tender, 2,000 gallons; weight of tender loaded, 36,000 pounds; train load, 120 tons behind the tender on 3 per cent. grade. There are fifteen flat cars, 24 feet long and 7 feet wide, with platform 3 feet 8 inches above the rail; some of these will probably be changed to coal cars; they were needed for construction work. There are ten coke cars, two box cars, and six coal cars, the latter with drop bottom and side gates, all of the same length, width and height as the flat cars, with 28-inch wheels. Freight cars have a capacity of 20,000 pounds. There is one combination coach 30 feet long and 8 feet wide. All cars have Westinghouse air brakes and Janney couplers. The couplers work nicely on the crooked road. All cars were purchased of the St. Charles Car Company.

An important item of the cost of the road is the freight charge on other roads on equipment, rails and lumber. It was found advisable to have home construction as far as practicable.

The following table gives some information concerning the bridges:

Class and Alignment.	No. of Bridges.	No. of Spans.	Total Length.	Timber Ft. B. M.	Approximate Height.
Single Spans or Bulkheads . . .	3	3	38	7,442	4 to 7 ft.
Pile Bridges	5	75	1,050	138,416	5 to 8 ft.
Trestles on Tangents	4	40	581	123,259	25 to 48 ft.
Trestles on 16 Degree Curves . .	2	16	218	33,940	20 and 25 ft.
Trestles on 24 Degree Curves . .	2	22	325	64,973	27 and 40 ft.
Trestles on Curves 30, 34 and 36 Degrees	4	37	526	89,410	25 to 35 ft.
Trestles on 40 Degree Curves .	11	101	1,565	300,435	20 to 45 ft.
Trestles on 45 Degree Curves . .	1	14	219	50,359	48 ft.
Trestles on Side Track	2	24	301	50,194	30 and 34 ft.
Totals	34	332	4,826	858,428	

The pile bridges, and one of the single spans, are in the valley, west of the mountains. It will be seen by the table that the gulches were all crossed at about the same height. It was thought to be advisable not to exceed fifty feet in height, for bridges crossing the gulches nor to lengthen the line by pushing up into narrow ravines, making a bridge less than thirty feet high. The gulches had to be crossed with curves, and places were selected by using a suitable curve which would keep the height of bridge within the limits. About one-half the places required 40° curves.

This bridge work covered one hundred days, with a gang of sixteen men and one team of horses. The work included framing and erecting, and practically amounted to 500 feet of timber per day to the man. A wire cable was stretched across the bridge opening at each place, and all the timber for the bents was lowered to place piece by piece and packed. The bents were then raised by using the cable. The deck was run out on dollies in the usual way.

The curvature on the line presents some interesting figures, which are shown in the following table:

Degree of Curves.	No. of Curves.	Angle, Right.	Angle, Left.	Total, Angle.	Length, Total.	In Feet, Average.
From 1 to 10 degrees	41	423° 28′	293° 30′	717° 18′	9284.8	226.4
" 11 " 20 "	59	1105° 15′	981° 17′	2086° 32′	13277.	225
" 21 " 30 "	44	1719° 49′	1127° 03′	2846° 52′	10531.5	239.5
" 31 " 40 "	42	1706° 11′	2414° 00′	4120° 11′	10521.4	250.5
45 "	1	. . . .	162	162	360	. . . .
Totals	187	4955°.03′	4977° 50′	9932° 53′	43974 8	234

Total length of line covered by these curves	72,125	feet, or 13.66 miles.
Aggregate length of all curves	43,974.8	" or 8.33 "
" " " tangents	28,150	" or 5.33 "
Average " " curves	234	"
" " " tangents	166	"

Longest curve is 16°, or 960 feet.
Largest angle is in a thirty-degree curve, 162° 54′.
Longest tangent is 657.5 feet.
Average curve extending over entire line would be 13° 46′.
Average curve extending over curved portion of line would be 22° 35′.

Sixteen of the above curves are compounds, but the parts are taken separately in the lists of curves. Compounds are taken as single curves in giving average tangent. The amount of angle right or left differs only 22°. The numbers of curves in the different groups, as above taken, do not differ greatly. The greatest number of curves are found to be 13—10°, 16—12°, 16—20,° 13—24,° 23—30,° 34—40°.

The cost of the railway in working order, including equipment, can be approximately taken at $12,000 per mile. As nine-tenths of the expense of grading and bridging occurred on the mountainous portion, the cost of this part comes to about $15,000 per mile.

The various items of cost are shown by percentage as follows:

Grading	30.0	per cent.
Depot grounds (grading)	3.0	"
Bridge material	5.0	"
Bridge framing and erecting	3.0	"
Ties	5.0	"
Engineering expenses	3.3	"
Rails and fastenings	23.0	"
Track laying and surfacing	4.4	"
Handling all material	1 3	"
Construction train service	1.6	"
Buildings	3.4	"
Equipment	7.0	"
Freight paid other roads	10.0	"
	100.0	"

In estimating the expenses of managing and operating the road, the force required and the principal items of salaries, wages, etc., were taken as follows:

		PER DAY.
OFFICERS AND AGENTS.		
Superintendent, 1 clerk; auditor, 1 clerk; 2 agents	Salaries,	$22 00
MAINTENANCE DEPARTMENT.		
Three foremen, bridge carpenter, 12 laborers	Wages,	25 00
TRAIN SERVICE.		
One crew		15 00
MACHINERY DEPARTMENT.		
Machinist, car repairers and supplies		12 00
Fuel—4 tons coal @ $6.50 per ton		26 00
Total		$100 00

It was expected that the superintendent would perform the duties of roadmaster, and that the bridge carpenter would obtain assistance from sectionmen and car repairers.

The laborers include those required for transferring at the junction. The smelter people were expected to load and unload cars at the works.

Machinists and car repairers would be under the direction of the superintendent of machinery at the works.

With a traffic of 120 tons per day, which will be about the average for the next two years, the cost per ton is 0.833. Interest charge on outlay for construction, $18,600. Interest charge per ton, 0.425. Total cost per ton, $1.258, or, approximately, 5 cents per ton per mile. This is rather a startling figure compared with rates at which the trunk lines of the country are doing business.

The line was completed and regular train service was put in operation the first day of December, 1894.

RIPARIAN OWNERSHIP OF LANDS BORDERING ON LAKES AND RIVERS.

By J. H. Armstrong, Member of the Civil Engineers' Society of St. Paul.

[Read December 3, 1894.]

The following paper treats of the method of establishing the side lines of riparian lot-owners over the beds of lakes and rivers.

We may take, as a basis, the proposition that all lots bounded by tide waters take to high-water mark, while lots bounded by the great lakes and navigable rivers, take to the low-water mark. In both cases they are entitled to all accretions and relictions. Lots bounded by non-navigable lakes and rivers take to the center of the stream, and include all islands not otherwise disposed of by the Government.

The method of establishing the lines from the point where the Government survey ends is the principal subject of this paper. Of course, when an agreement cannot be arranged between property owners, the question has to be decided by the courts, yet the surveyor is a very necessary factor in the case. To him it is given to make the surveys and to mark such subdivisions as his judgment dictates, estimating quantities and preparing the engineering part of the case for the Court. The Court, not being a surveyor, takes the plans and evidence at hand and decides accordingly. If the plans and evidence are faulty, the case may be decided contrary to its real merits; consequently the surveyor should be fairly well posted in the decisions of former cases or his clients may suffer.

We will now take up the matter of lots bounded by rivers.

Fig. 1.

Fig. 1 will illustrate the point to which I wish to call your attention, viz.: the subdivision of the river bed and the extension of the side lines over those islands under the common law. I have shown here a portion of the Mississippi River, with several small islands.

Just south of lot 3, section 6, you will see a small island. You would naturally suppose that that piece of land belonged to the owner of lot 3; yet, should the deep water channel be north of that island, no matter if only 100 feet wide, the title to that island and to the one in the center of the river goes to the owner

of lot 8. Now, the common law is supposed to dispense common justice to all, yet I see but little of the latter article in the provision of the law in this case. The old Roman law, by Gaius, states that if an island rises in the middle of a river, title to it is divided between the property owners on each side: if on one side, it goes to the nearest property owner. This looks more like justice.

Of what use is the deep-water channel to the owner of lot No. 8? To reach it he would have to wade through one-half mile of water from one to two feet deep. He would not be allowed to construct, for shipping purposes, a dock running out to that point. He is entitled simply to one-half of the last drop of water in the river, and this title is a phase of the question that will give us but little trouble. Navigable rivers are not in the habit of going dry. We may have low water for a few weeks in each year, but the stream may be full to the banks for the balance.

To illustrate the situation, we will suppose that the owner of lot 8 takes possession of those islands and improves them. They may be very valuable. Then a gradual change of channel takes place, the river cutting away the south bank until lot 8 entirely disappears. Of course, the owners of lots 2 and 3 would extend their lines to the south. In fact, I know of no limit to the extension, for the law provides that owners of lots bounded by rivers, being subject to loss, are not to be held accountable for their gains. (See Jefferies *vs.* The East Omaha Land Company.) You can see at a glance that fixing the boundaries in that neighborhood would be attended with some difficulty.

Then we will take lots 2 and 3, section 5, and suppose that a large amount of land has formed along their frontage. How are we to correctly divide these accretions amongst the lot-owners? The land thus formed is sometimes of great value, and, as the case often arises, the matter is worthy of your careful attention.

Prof. Johnson, in his excellent work on surveying, gives, as a rule, that we start at the original meander line and run to the center of the river, as nearly as possible at right angles with the general course of the same. This seems to be somewhat in conflict with the instructions of the General Land Office and the laws adopted by Congress in 1805, which direct that "the lines of fractional sections shall be established by running from established corners due north and south or east and west to the water course, Indian Reservation or other external boundaries of such fractional sections." . . . As an illustration, we will take the case of Jefferies *vs.* the East Omaha Land Co. (Supreme Ct. Reps., Vol. 10, p. 519). The case was tried in the United States Circuit Court before Judge Brewer, and in summing up he quotes the statute of 1805, directing that the lines be run due north and south or east and west, and decides as follows:

"These views result in the conclusion that the side lines of Lot 4 are to be extended to the river—not as the river ran at the time of the survey in 1851, but as it ran at the time of the patent in 1855, and that all land which existed at the latter date between the side lines so extended and between the line of the lot on the south and the river on the north was conveyed by the patent."

The case was carried to the United States Supreme Court, and the decree of the Circuit Court was sustained.

I consider this case of great importance, sustaining the point which I make, that the lines should be extended to the bank of the river and then deflected, the common law continuing the survey from that point.

The west line of the lot in question was the west line of Section 21, Township 75 N., Range 44 W.; and the lot was bounded on the north by the Missouri River. It originally contained 37.24 acres, and the accretions amounted to 40 acres more, the side lines being extended north about 1,320 feet. The first course of the original meander line, starting at the west line of Section 21, was S. 71° east. Should you start at the original meander corner and run a line at right angles with the river a distance of 1,320 feet, you would be about 450 feet east of where the line is now placed, a difference entirely too great to be lightly considered. It stands to reason, that the water course means the bank of the river; that is to say, no attention would be paid to overflowed meadow lands, nor would the lines be extended over a portion of the river bed on account of low water. I am aware that by producing the lines to the river bank, lot-owners may sometimes lose a water frontage; but with that the surveyor has nothing to do. He is making a survey under the instructions of the United States Government; and if these instructions mean anything, they mean that the lines shall be extended due north and south or east and west. It may be said that the lot, as bought by the owner from the Government, had a frontage on the river, according to the official survey; but it must be remembered, also, that he bought that piece of land under the laws adopted by Congress in 1796 and 1805, which give full directions how those lines shall be established. Any land-owner can plat his land, and give full instructions how the lot lines are to be extended over a pond on his land or the accretions along a river front; and if those instructions are plain enough, no law can change them. City lots, bounded by a pond, would be deflected at the point where the water line originally cut the lot line, unless a clause in the original plat directed otherwise. It seems to be no more unjust that a lot-owner should lose a small water frontage, for which he receives what is sometimes a valuable addition to his land, than that another should lose his entire lot, for which he receives nothing, while his neighbors on the opposite side of the river gradually extend their lines over and take possession.

Now the establishment of the side lines from the bank to the center of the river must be done under the common law. Where no lines have been established by the Court, I would give as a rule, that the first lot line on each side of the place where the work is to be done, that strikes the river practically at right angles, be selected and produced straight to the center line of the river; then measure the distance along the river bank, running straight from the intersection of the lot lines with the river bank, between the two lot lines first named; then ascertain the entire distance along the center line of the river between the two lines so extended, and give each lot-owner a distance on the center line equal to his frontage, plus or minus his apportionate share of the difference between the two lines. This method is practically what is known as the Massachusetts rule, and is certainly a very equitable one. I have given an illustration of this rule in Fig. 1, where the lot lines on the south side of the river are so extended. The center line I have shown on the diagram is a line midway between the original meander lines; but the rule will apply as well for the center of the channel.

In concluding the discussion on lots bounded by rivers, I will say that I see no reason why the general government, when issuing the original patent, should not limit the riparian rights of the lots to a line midway between the original meander lines. That would give us a good basis for future surveys, and would avoid the confusion which nearly always arises over the ever-changing channel.

We will now turn our attention to the subdivision of lake beds amongst the riparian owners. That is, perhaps, the most difficult problem the surveyor has to contend with. As I have before stated, the accretions and relictions belong to the riparian owners. By accretions, I mean the amount added to the land by the action of water washing up material; by relictions, lands uncovered by the change of channels in rivers or by the recession of water in lakes. All cases carried to the Supreme Court have been so decided. However, some doubts about the matter must have existed at Washington, for the Land Department, as late as 1877, would, on application, cause to be surveyed and disposed of as other public lands, reclaimed lake beds which had already been meandered and the adjoining lots disposed of. That certainly was in opposition to the common law governing such cases, for the Supreme Court says that when a patent is issued for land bounded by lake or stream, the title to the land under the water passes from the Government. See Harden *vs.* Jordan, Supreme Court Rep., Vol. 11, page 808 (1891). Chief Justice Miller, in Moore *vs.* Robbins, says: . . . "with the title passes away all authority or control of the Executive Department;" and again, referring to the power of the Secretary of the Interior, "after the patent, he is absolutely without authority."

Then, the riparian owner taking to the center of the lake, and there being no restrictions in the original patent, we have to subdivide the lake bed under the common law, which takes effect where the Government survey ends.

The lake shown in Fig. 2 is situated in West St. Paul. It was meandered in the original survey in 1853, and adjoining lots were sold. In 1861 the bed of the lake was subdivided by the Government and disposed of as public land. Litigation over the ownership in the bed of the lake commenced in 1872 between the riparian owners, the State, claiming under the swamp-land grant, and different railroad companies, and was finally settled in 1894 in favor of the riparian owners. So the case was before the courts, in one shape or another, for a period of twenty-two years. You can imagine the costs. Then came an action for partition amongst the riparian owners of the lake bed, and it was subdivided under what is known as the Massachusetts rule, which I fully illustrate in Fig. 2.

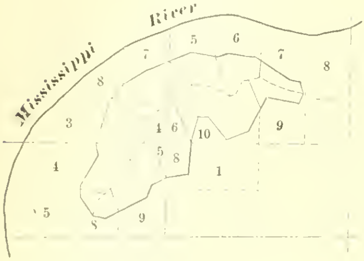


Fig. 2.

I do not consider the above as a fair test of the rule, it being more of an agreement amongst the property owners than a trial on its merits. However, it is the most equitable rule yet advanced for a subdivision of lake beds, and I have no doubt it will be sustained by the higher courts, I understand that the rule will be further tested in a case to be tried soon. It will be watched with interest. The method of subdivision under that rule is as follows:

The center line is established by running midway between the original meander lines from the northwest to the southeast end of the lake. The distance is then measured on the northeast side, commencing at the intersection of the center line with the meander line and running straight to the intersection of the west line of lot 4 with the meander line, then running straight to the intersection of east line of lot 4 with the meander line, and so on to the intersection of the center line with the meander line at the southeast end of the lake. Then the distance is measured on the center line, and each lot-owner receives, on the center line, a distance equal to his frontage, plus or minus his proportion of the difference between the two lines. The southwest side is subdivided in the same manner. It is hardly necessary to state that it would be impossible to establish the center of the lake by attempting to use the water lines, for a boundary established in that way during the high water would probably differ all the way from 100 to 1,000 feet from

one established during low water, and according to that method both surveyors would be right.

In Fig. 3 I have shown four lakes meandered by the Government surveyors in their original surveys. They are now dry and fit for agricultural purposes. They are a fair specimen of the many to be found in this State. Lake "A," being long and irregular, is subdivided according to the Massachusetts rule. Lake "B," being nearly round, the side lines are drawn to a common center; that being the only way in which to apportion the bed of a round lake among the different lot-owners. The side lines around lake "C" are drawn to a common center. On lake "D" the Massachusetts rule is used. This figure is made to illustrate the method of subdivision, and although but little care has been taken in the make-up, I doubt if a court decision would materially change the side lines. Imagine each lot-owner having his portion of the lakes surveyed and fenced. Lake "B" would look like a clumsily constructed cart-wheel. Of course, in many cases two or three lots might belong to one owner, and this would improve the appearance of the picture; but it is quite possible that each lot is owned by different parties; in which case, under the riparian laws, their lines would be substantially as shown on the diagram.

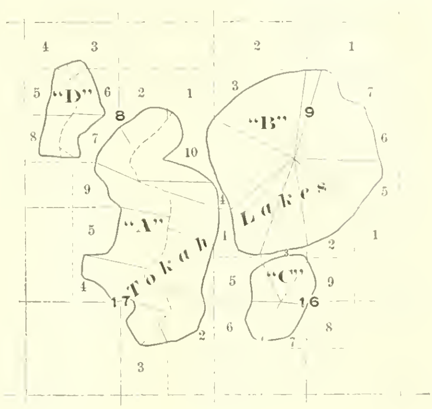


FIG. 3.

Now, as to the amount of the lake beds received by each owner. Lot 4 in section 9, containing 3.3 acres, received 29 acres in lake "B" and 19.3 acres in lake "A," section 8; and lot 4 in section 16, containing 18.4 acres, receives 48 acres in lake "B" and 34.4 acres in lake "A"; lot 3, section 16, containing 7½ acres, receives 38 acres in lake "B" and 20 acres in lake "C"; lot 10, section 8, containing 33.3 acres, receives 44 acres in lake "A" and 42 acres in lake "B." A party buying lot 4 in section 16, lot 4 in section 9 and lot 10 in section 8, would have to pay for 55 acres of land, and would receive as his share 217 acres of the lake beds—not a bad investment.

Of course the subdivision of the small lakes, around which the land has already been surveyed and disposed of by the general government, must come under the common law and the decisions of the court, or by agreement amongst the different lot-owners; but, going on the principle

that it is never too late to mend, why not have inserted in all future patents a clause which would permit the riparian owner of a fractional lot bounded by an unnavigable lake to take only so much of the lake bed as is required to fill out the lot of which he holds the fraction? For example, lot 4, section 9, would receive 40 acres in lake "B" and so on, the balance of the lake bed going to the State as school lands or for other purposes. In this way the rectangular system of surveys would be preserved, and when the fractional lot passed from the Government, its boundaries would be fixed for all time. Of course, when I say a full 40 acres, I mean plus or minus their proportion of the shortage or surplus in the section; very few sections containing exactly 640 acres.

I am aware I have given but little information in this paper, and that little perhaps not of the best, yet if I can get the matter generally discussed, a better understanding will be arrived at and my object attained.

THE STATE TOPOGRAPHICAL SURVEY OF MINNESOTA.

By W. R. Hoag, State Topographer, Professor of Civil Engineering in the University of Minnesota, Member of the Engineers' Club of Minneapolis.

[Read November 19, 1894 *]

Among the needs of the people, those which are thought to fall to the Government or to the State for supply are, as a rule, slow in receiving just recognition. Whenever this tardiness becomes sufficiently pronounced, private capital steps in and often supplies the need, much more quickly and fully than public sentiment would have justified Congress or legislatures in doing. Tradition is strong, and we are slow to delegate to the Nation or to the State the control of those institutions which are now serving the people acceptably. Especially is this true of those which have had their birth and their doubtful beginnings since the establishment of our government. The railroad, the telegraph, the telephone and the express service might be named as examples in point.

There can be no doubt that the present great activity in the world of thought and of letters is directly due to the maintenance of our postal system upon the present plan, which imposes upon those employing it a tax too small to pay for the actual service rendered, to say nothing of a good profit such as must obtain if the work were to be long continued as a private enterprise, and which thus, in order to lighten the load of those who use it largely, imposes upon those who employ it but little, a tax disproportionate with the accommodation furnished them. The propriety of this arrangement is a legitimate topic of discussion for the political economist, yet all are agreed as to the great benfits conferred by the system as it is.

Who shall say what we, as a nation, have lost in activity and in consequent development by permitting our telegraph system to remain under private control, with rates and conditions in no way calculated to encourage its further adoption and as a rule prohibitory except where cost counts for naught or where the time element is a ruling consideration. The great question of transportation; not that much mooted question whether the Government should now acquire control of the rail and water ways of the country, but whether our territory would not have been developed much more rapidly and whether the strengthening and enriching effects of an efficient and economical system of transportation would not be present in a much larger measure than they are to-day had the Government from the first developed railroad transportation as it has developed the postal system.

* Manuscript received December 31, 1894.—*Secretary, Ass'n Eng. Socs.*

There is another class of needs which a civilized community soon comes to feel, but which, being of a more general nature than those already noted, has received but tardy recognition, especially in this country where the national government has taken up the work only after urgent specific needs have demanded consideration. I refer to the need of surveys of the public domain, whether conducted in order to discover the resources of the country as a purely geological and natural history survey, or as a topographical survey in order to meet the multifarious needs of our modern civilization.

Even the need of some scientifically consistent plan of description and partition of the land thrown open to settlement did not move Congress till a large amount of such lands had been disposed of and in a manner giving the most absurd and expensive plan for farm boundaries and unduly increasing the cost and uncertainty of all subsequent land surveys and descriptions. When finally the rectangular system of our public land surveys was devised and adopted, about 1810, the standard of desirable accuracy was placed so low, the execution of it by inexperienced contractors was so lamentably poor, and the government inspection of it was in many cases so farcical, that the resulting additional cost to the people from litigation has been estimated as already far exceeding what would have been necessary to make an absolute topographic survey in which every important subdivision line would be given exact position by a system of triangulation and traverse all having ultimate control in a rigid system of geodetic triangulation.

In 1790 it was seen that there was needed an exact knowledge of our coast line, both for developing and protecting the shipping interests and for purposes of public defense, and to meet this need the U. S. Coast Survey was organized. It began this great work in 1807. In 1841 the Lake Survey was organized for the definite purpose of making a geodetic survey of our shore line on the Great Lakes. In 1878 the Geological Survey was given the special work of conducting geological researches in the western territories, and it has since extended its field to the whole country. More recently it has confined itself principally to topographical surveys, in the absence of which it found itself unable to prosecute with satisfaction its geological studies. The coast lines, except those of Alaska, having been about completed in 1870, the work of the Coast Survey was enlarged by Act of Congress in 1871 so as to include hydrographic and topographic work on the great rivers of the country except the Mississippi and Missouri rivers, which had been assigned to special commissions in charge of the Army and Navy.

The Coast Survey, with the broadened title of Coast and Geodetic Survey, was also instructed to conduct a grand system of transcontinental triangulation and precise levels, not only for purely scientific purposes,

but also in order to co-ordinate its own work and that of any other agency. The exercise of this latter function was expected to aid especially in fixing international and interstate boundaries and thus to encourage State work of similar character. To still further aid each State in prosecuting its topographic survey, the U. S. Coast and Geodetic Survey was authorized to conduct a separate triangulation as a basis for such surveys in those States which had shown sufficient appreciation of the value of such by having put in vigorous operation their own State geological surveys.

To the U. S. Coast and Geodetic Survey was also entrusted the work of conducting a magnetic survey of the country.

And so, as special needs have arisen, they have been supplied either by a special agency or by giving the work given to some agency already established, to whose work that in hand was most closely related.

Congress has not seen fit to create an institution whose prime function shall be to make a complete and accurate topographic map of our whole territory. Nor is it likely to do so, for it has already created a number of distinct surveys, more or less national in character; one of whose functions is to make such a survey of its immediate locality, and the avowed purpose of one of the lines of work of its oldest survey—the Coast and Geodetic—is to assist the different States in carrying on their own surveys.

A further reason why the plan of individual State surveys is likely to prevail is the pride felt by each State in discovering and developing its own resources and in building up its own state institutions. In fact, each State desires that the needs of its citizens may be supplied as far as possible within the State and from its own resources.

Another difficulty in the way of inaugurating a general plan covering the whole country, appears when we consider that, on account of local difficulties, coupled with the desirability of great accuracy and full detail, the accurate mapping of some sections of the country might cost from two to five times as much as that of others.

Again, some States, from a keen appreciation of the economic worth of a reliable topographic map, would desire much more detailed and more expensive work than could be carried out in other States on any generally equitable plan. Just this has already happened in Massachusetts, where the National Geological Survey proposed to conduct the State topographical survey if the State would meet half the expense. In arranging the details of the contract, it appeared that the Geological Survey desired to do the work according to the plan which it usually followed elsewhere under like topographic conditions; but the State commission objected to this plan, claiming that the State could not afford to meet even half the expense of such a survey, which would produce a map but little better than the one already in existence.

In other States, by reason of general inactivity in all matters relating to public improvement, even a map of average cost would satisfy no present need, and all money so expended would become lost to the country until the State should awake to an appreciation of its true worth. On the other hand, it would be a manifest injustice not to carry the work along about equally in the different States.

Another evil which must attend the operation of such a plan is the following: Any national survey must have at its head a director or superintendent with power to direct the details of the work; the general policy alone could be fixed by Congress. The Survey, dependent upon the continued favorable action of Congress for maintenance, will, if it be loyal to its own cause, endeavor to merit and to gain the support of a majority in Congress. But congressmen, as a rule, are keen to see that their own States receive their full share of the benefits from such legislation. A system of political trading results, and friendly relations are maintained by doing work in some States and giving promises in others, sufficient to control a safe majority in Congress. The operation of such a system must result in a shifting policy, with a discontinuation of the work in some States in order to resume operations in others, following closely and actively every change in the political color of Congress. And thus a great agency, created to serve the best interests of the people impartially in a specific work, must soon degenerate into a vast political machine, an incidental feature of which is to do topographical work, while its main function is to serve Congress. While this picture may to some seem overdrawn, I firmly believe that, in view of the difficulties present, some of which I have specified above, any such survey would arrive at substantially this condition even before it could become efficiently operative.

Indeed, our country has already furnished proof of this certain tendency, and the development has progressed sufficiently to enable one familiar with the *modus operandi* of our national surveys to see the analogy. This difficulty can easily be avoided by allowing each State to take up its own work at the time and in the manner which seem to it best, conserving equally all the interests of the State and allowing it to receive from the general government whatever aid it may without sacrificing its control of its own work.

Although many States are at present engaged in conducting topographic surveys, according to one plan or another, only three—Massachusetts, Connecticut and New Jersey—have completed such surveys. In fact, we are far behind other nations in the appreciation of the economic value, to a State, of possessing, comparatively early, an accurate topographical map of its territory. As a natural result, we find that few States have taken advantage of the valuable co-operation

offered by the U. S. Coast and Geodetic Survey in furnishing free to the State for its topographic survey a triangulation which, as a foundation, must precede all topographic work proper, Minnesota being the ninth in the list thus co-operating.

The mining engineer fully realizes the value of a reliable topographic map of that section which is to be the field of his professional labor.

The municipal engineer knows that only by the aid of an accurate topographic map can he with certainty discuss questions relating to sources of water supply or to the location of reservoirs and standpipes, or trace out lines of natural drainage for use in designing systems of sewage disposal.

To the sanitary engineer such a map becomes a valuable aid in searching out sources of contamination in wells or in surface supply.

The geologist requires the aid of the topographic map for the fullest exposition of his results, especially in problems touching physical, stratigraphical and glacial geology.

The hydraulic engineer would need little else in determining the site and value of mill privileges, or in studying the overflow of land adjacent thereto.

The survey is of great value in prosecuting studies in natural history and meteorology, while to the civil engineer an adequate topographic map is the foundation upon which nearly all his problems must rest.

It has been estimated that Massachusetts alone has paid since 1836 $20,000,000 in railway expenditures over what would have been necessary had it possessed at that time accurate topographic maps of its territory.

The army engineer can increase in a large measure the efficiency of the army by supplying it with topographic maps, enabling it to take advantage of every important feature which a map would clearly show. Our late civil war was undoubtedly prolonged not a little by reason of the superior knowledge possessed by the Southern generals, gained mostly by hastily prepared maps of their own territory, made immediately before and during the war.

To the agricultural districts the topographic map proves of the greatest value. It would aid the establishment and maintenance of a scientific system of highways, which to-day imposes the severest tax the farmer pays. It would give a uniform and absolute means of referencing land lines and corners, and data for settling all questions of land drainage or irrigation.

If further proof is desired showing that the people appreciate the need of better maps of our territory than those furnished by the original

land surveys, made half a century ago, it appears in the fact that private concerns have prepared such maps and have found for them among the people sufficient sale to justify the undertaking. The more settled portions of our State have already been twice surveyed and mapped in this way, and certain sections much oftener.

The foregoing are named as among the leading benefits to be derived from a reliable topographic map, and are offered only as part of those in which the survey would furnish the means for an economic solution of important questions. For every public improvement, while serving the immediate purpose for which it was made, goes further and creates new industries which in turn make new demands upon it. Engineers fully appreciate this, for where a public survey is lacking, they must either supply the deficiency by a special survey, or reach a doubtful conclusion from an imperfect co-ordination of the known factors.

Legislatures are apt to be slow in arriving at a full appreciation of the situation, and to favor moving very slowly at first, which I believe to be wise considering the permanent character of the work and the desirability that the triangulation, which is the foundation, shall be adequate to meet any demands likely to be put upon it, and considering also how few are professionally prepared to conduct such work.

A cheap and hastily prepared map is of little value. It serves chiefly as an object lesson, teaching the people by contrast the worth of a true topographic map. The rejection of maps based upon old surveys in favor of those of higher accuracy and greater detail has been the history of topographic surveys up to the middle of the present century. Many of the European States have thus covered their territory with repeated surveys.

Shall our State acquire an adequate topographic map by this costly method of development and repetition, or shall we, by adopting the modern practice of the science, prove that we do not need these costly lessons and begin our work upon the plan now universally adopted by every country on the globe at present conducting a topographic survey? This question received its first answer in the State legislature of 1872, which committed us to the policy of conducting our own topographic survey, to be based upon such actual surveys and measurements as may be necessary to produce an accurate map of the State.

This was the provision made in Section 5 of the act creating the Geological and Natural History Survey, which was drafted by W. W. Folwell, President of the University, introduced in the legislature by Senator J. S. Pillsbury, a regent of the University, and approved by Governor Horace Austin, March 1, 1872.

A second answer to this question was given in 1887, at which time, upon recommendation of N. H. Winchell, State Geologist, the writer

was appointed, by the Superintendent of the Coast and Geodetic Survey, Acting Assistant, and given immediate charge of its operations in this State.

The object of having these acting assistants appointed by the Superintendent of the U. S. Coast and Geodetic Survey, was to bring that part af the work requiring the most expensive instruments and the most rigid field methods and office reductions under the direct supervision of one central, highly professional authority. This alone insures that uniformity necessary where each State survey is to form, besides the unit in the State survey, an integral part of the one continental survey. It saves to each State the expense of providing costly instruments, needed only at stated times during the progress of the survey, as well as instruments for conducting the primary triangulation, vertical measures, leveling and magnetics. The general direction and care of the field-work is in the hands of officers of lifelong experience, and the reduction of the notes is made by professional computers at Washington. This assures that degree of accuracy which is essential to the objects of the survey; while, at the same time, local interests are conserved by the fact that the actual field-work is executed by citizens of the State, all the expenses of the work being borne by the National Survey.

Work was begun early in June, 1887, and it has continued almost uninterruptedly during the summer months, which were rendered available to the writer by freedom from other University duties, and which, at the same time, were most suitable for carrying on the field-work. During this time, astronomical latitude and azimuth and telegraphic longitude have been established at a station in the University grounds to serve as the absolute starting point of the survey. A primary base-line five and a half miles in length has been prepared and measured, located along Snelling Avenue, St. Paul, which furnishes the element of distance to all lines. A line of precise levels has been run from the nearest sea elevation bench mark to this base-line, thus giving it sea elevation. From this base-line, with its direction, latitude, longitude and sea elevation accurately known, a complete system of triangulation has been extended over the greater part of Hennepin, Ramsay, Washington, Dakota, Goodhue, Wabash and Winona counties, fully preparing this territory of about 2,500 square miles for the topographic work proper. Besides this important work, a reconnoissance looking to a plan of triangulation has been done in Chicago, Anoka, Wright, Carver, Scott, Rica, Dodge and Olmstead counties. For the past two years observations of magnetic declination have been made at all the stations occupied, with the view to making, at an early date, a complete magnetic map of the State for the use of all county surveyors. During the past season, employing

instruments loaned by the Coast and Geodetic Survey, the Civil Engineering Department has been conducting systematic observations at a magnetic station located at the experimental farm, for the purpose of studying the laws of change in the magnetic elements and preparing for the issuing of the magnetic charts. The past season has been spent in work upon a topographic sheet covering the twin city district, about 225 square miles. The first part of the season was devoted to the planetable triangulation, and the latter part to filling in the topography. Most of the latter work was confined to the interurban district west of Snelling Avenue, and to that extending along the Mississippi River and lake and park regions of the cities where the city records do not furnish adequate details.

The Superintendent has ruled that during the progress of the field-work of triangulation, in addition to locating the primary stations, which are 15 to 25 miles apart, the Acting Assistants shall be allowed to locate other objects, such as church spires, tall chimneys, towers, etc., for use as secondary stations for the State Topographic Survey when such location can be made without extra cost to the National Survey.

Since economy, as well as accuracy, demands that the primary stations be located in most cases as far from each other as possible, it is of the greatest importance that these secondary points—in sufficient number and in favorable positions—be chosen and located during the progress of the primary work. Especially is this true when tall observing towers must be erected at the primary stations in order to overlook surrounding woods or intervening ridges, for such towers are not likely to remain in position till they are needed by the State in its topographical survey.

In such a case the secondary and tertiary stations could not be located except by rebuilding the original towers, incurring an expense and delay in the topographical survey which the State could ill afford.

During the progress of the work in Hennepin, Ramsey, Washington and Dakota counties, but three towers were required, and a sufficient number of church spires, wind-mill towers, etc., were located as secondary points.

Quite the opposite conditions are met in Goodhue, Wabash and Winona counties. Here towere ranging in height from 24 feet to 64 feet, are required at nearly all stations, and owing to the small number of objects sighted but few secondary points could be established except wind-mill towers, which, from their great number and similarity, proved of very little value since all attempts at identification proved futile. This latter difficulty, which threatened to seriously impair the usefulness of the main triangulation to the State topographical survey, led the regents of the University of Minnesota, in the spring of 1892, to the

appointment of the writer as State Topographer, with instructions to make what observations were needed and to establish such secondary stations as would render the present work of the State triangulation of the greatest possible use to the State Topographical Survey.

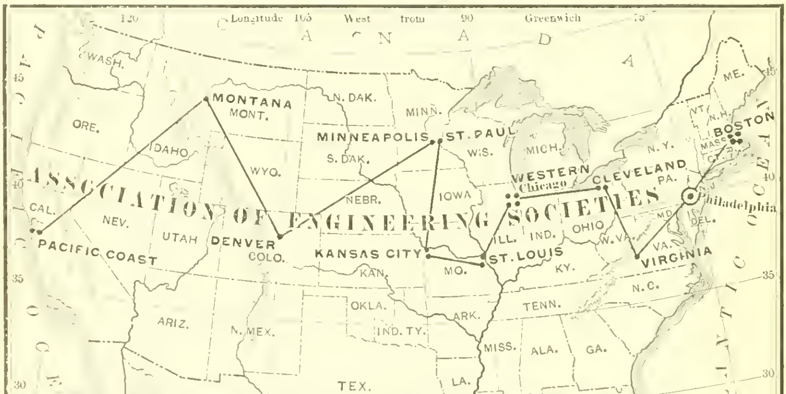
A topographical survey, such as is contemplated by a State, is a survey based upon absolute geodetic points and conducted by actual measurements and observations, the methods and the degree of accuracy throughout being sufficient to permit the construction of a map capable of showing accurately all topographical features as to *distance, direction* and *elevation; i. e.*, to show accurately in position, shape, direction, character, elevation, etc., all lakes, rivers, hills, ridges and valleys; woodland, prairie or cultivated land; lines of cultivation; government lines and corners; all highways, railroads and canals; all buildings in the country, in villages and in cities; with contour lines which would show all lines of natural drainage, the grade or pitch of all roads, the descent of all rivers, etc. Besides these, together with many other details which would be represented on the map, the survey comprehends a published report, issued at convenient intervals during the progress of the work, which shall contain, besides the usual report on general progress of the work, expenditures and estimates, etc., a full account of all methods and a description of the instruments employed, and of the methods and results of the office reduction and computation. The principal purpose of the report is to show, more accurately than the map, the exact data gained by the field-work. Such accuracy is necessary for the proper continuance of the field-work and for various practical and scientific uses of the survey. The value of such a survey to the State need not be argued, for the history of the progress of topographical surveys in every civilized country on the globe is sufficient proof of it. The older and more advanced nations, as England, France, Germany and Spain, have been the leaders in the sciences of topography and geodesy, each devoting large sums of money to provide accurate and reliable maps of its territory.

THE CONTRIBUTION BOX.

Members of the associated societies, and other persons, are invited to send to the Secretary, for this department of the JOURNAL, such matters of general interest as may come to their notice.

From Ocean to Ocean.

In the Contribution Box for December, 1894, we chronicled the decision of the Western Society of Engineers to continue its membership in the Association of Engineering Societies; in January, 1895, we welcomed to membership the Denver Society of Civil Engineers and the Association of Engineers of Virginia, and we now have the pleasure to report the application of the Technical Society of the Pacific Coast for membership in the Association.



Bradley & Poates, Engr's, N.Y.

Upon the admission of this society, the union of American engineering societies, effected by the Association, will extend from the Atlantic to the Pacific, and will thus become longitudinally co-extensive with the union of American states.

With the Boston Society of Civil Engineers (one of the original four) upon the Atlantic, with the Technical Society of the Pacific Coast at San Francisco, and with societies in Virginia, at Cleveland, O., Chicago, Ill., St. Louis and Kansas City, Mo., St. Paul and Minneapolis, Minn., Denver, Col., and Montana, the Association embraces 52 degrees of longitude and 10 of latitude, and its JOURNAL may be taken as fairly representative of the various phases of American engineering practice.

The Board of Managers of the Association consists of one representative from each society of one hundred members or less, with one additional representative for

each additional one hundred members, or fraction thereof over fifty. In the map given herewith, each society is represented by one dot for each of its representatives on the Board.

The aggregate membership of the associated societies is now nearly 1,500. There were published in 1894 nearly 1,000 pages of papers, proceedings and index to current technical literature, and the JOURNAL has now reached a circulation of about 2,000.

The advantages of the co-operation thus secured, in the economy effected and in the interchange of ideas afforded, are so manifest that it would seem inevitable that the system thus established should rapidly extend its scope by giving rise to the formation of new local and sectional societies which should profit by the means thus afforded for the publication of their papers and proceedings.

Articles of Association and Chairman's Report.

For convenience of reference, a number of copies of the form containing the Articles of Association and the Report of the Chairman of the Board of Managers, have been reprinted from the January JOURNAL, and they will be sent to members of the associated societies upon application.

Mutilated Plates.

It appears that, through carelessness at the bindery, the plate accompanying Mr. S. Bent Russell's paper on "Points of Interest in the Design and Construction of the New St. Louis Water Works," in the January JOURNAL, was sheared in trimming some of the copies of the JOURNAL.

The Secretary is prepared to furnish new plates to replace any thus mutilated.

The Western Society's Membership.—Correction.

The attention of the Secretary has just been called to an unintentional misstatement of the membership of the Western Society of Engineers in the table on page 111 of the January JOURNAL, where the numbers of pages per member, contributed by the various societies, are compared.

For the purpose of this comparison, the mailing list for December, 1894, was taken as indicating the membership of the societies, but it now appears that a number of members of the Western Society had been dropped from that list pending payment of dues, without, however, forfeiting their membership in the society.

Judging from the table given on page 105 of the same JOURNAL, the membership should have been stated at about 350, instead of 293. This would, of course, affect the figures in the second and fourth columns, but, as the comparison was given simply as a matter of general interest, it is perhaps not worth while to print a corrected table.

Engineers' Office Buildings.

Two years ago, when the question of improved quarters for the American Society of Civil Engineers was being discussed, the Collector ventured to suggest to

that society the wisdom of uniting with its sister societies, at least with those of the mechanical, mining and electrical persuasions, to erect a joint office building for the use of the several societies.

Such a building, it was felt, would give the societies vastly improved accommodations, would establish an engineering headquarters in New York City (inasmuch as engineers of all branches would surely find it to their interests to occupy offices in such a building) and, last but not least, would form a handsome source of revenue to the participating societies.

It will be seen that the proposition amounted simply to this: that the great national societies having headquarters in New York should unite for the purpose of securing a home, as our local and sectional societies have united in the Association of Engineering Societies for the purpose of publishing their proceedings.

Although, to all appearances, no steps have been taken in the direction suggested, the Collector believes that it is merely a matter of time when the societies will realize the advisability of such a step. Already we notice, as a straw indicating the direction of the wind, a movement on the part of engineers in Chicago toward something of the same sort of concentration as is here suggested.

The Western Society of Engineers has long been in want of better quarters than those previously occupied in the now antiquated Lakeside Building, and the Society, by acting in co-operation with a number of engineers who were similarly situated, and by taking a large amount of space in the Monadnock Block, were enabled to secure more favorable arrangements than could otherwise have been effected.

One of the engineers in question writes: "We are very comfortable in this building, which now contains, no doubt, more engineers and persons connected with engineering occupations than any other."

Progress of the Metric System.

The Box is informed that Congress has passed a bill providing for a commission to report upon the propriety of introducing the metric system of weights and measures into the United States. The commission consists of the Secretary of the Treasury, the Director of the Mint and the Superintendent of the Coast and Geodetic Survey—Messrs. John G. Carlisle, Robert E. Preston and William W. Duffield. It is expected that the report of the commission will be made to the Fifty-fourth Congress when it meets.

The adoption, by Act of Congress, of standard units of electrical measurement based on the metric system, has been completed by the report to Congress of the National Academy of Sciences, to which was intrusted the duty of prescribing specifications of details necessary for the practical application of the definitions of units.

In England, on February 13th, the House of Commons appointed a select committee to inquire whether any and what changes of their weights and measures is desirable. There is reason to hope for a report favorable to the metric system.

Timber Physics.

Thus far between thirty and forty thousand tests of timber have been made at the laboratory at Washington University, St. Louis, under the auspices of the Forestry Division of the Department of Agriculture.

As a result of these tests, a number of generally held opinions respecting timber have been reversed and others modified.

It has been shown, for instance, that seasoned lumber is about twice as strong as green lumber, but that well-seasoned lumber, if soaked in water or left for a time in a damp place, loses its strength with the absorption of moisture. On the other hand, when the moisture is diminished below 4 per cent., a slight decrease in strength begins to appear.

Again, it has been demonstrated that timbers of large section have equal strength per square inch with smaller ones, when they are equally free from blemish.

Another time-honored tradition which has been relegated to the lumber loft is that knots, while weakening a beam, do not affect the strength of a column. The tests at St. Louis have fully established the fact that a knot is as great a source of weakness in a column as in a beam.

That the tests in question have dissipated the venerable prejudice against bled timber is now well known.

Finally, the tests show that long leaf, or Georgia pine, is stronger than average oak.

In Alabama, along the Louisville and Nashville Road, a large amount of chestnut oak was felled a few weeks ago for the tanned bark alone, the wood being allowed to rot because its value for railroad ties was not known. The Division of Forestry, in a circular, called attention to the superiority of this timber for ties, and the wood is now utilized, effecting an annual saving, for that region alone, of from forty to fifty thousand dollars, or more than three or four times as much as the annual appropriations for the Division of Forestry.

Topographic Maps of the United States Geological Survey.

As a basis for its geologic representation, the U. S. Geological Survey is preparing, through actual survey, a series of topographic maps, which, when completed, will cover the entire United States. For convenience of designation, the maps, which are about 19 by 22 inches in size, are listed under a State series heading, and receive, as a sub-title, the name of the most important city within their limits, thus giving a suggestion of the locality covered.

So far, nearly 900 maps have been issued. They are prepared on a scale of 1 : 62,500 and cover one-sixteenth of a degree of the earth's surface. The physical features of the country are well represented, and the contour delineation, on a scale of 20-foot intervals, must make the maps valuable as an aid to engineering enterprises where an accurate knowledge of the country is indispensable. The political geography is well followed, and the various roads and railroads are given.

In the distribution of these sheets, the Director of the Survey has endeavored to place the maps in the possession of those who have actual need for them.

Application should be made, through a member of Congress, to the Director of the United States Geological Survey, Washington, D. C.

THE LIBRARY.

It is proposed to notice briefly, in this department of the JOURNAL, such engineering publications as may find their way to our shelves.

Publishers are requested, in sending works for review, to state the prices of same.

Rankine's Civil Engineering. NOTES ON ——, after the Notes of Prof. William Allen and G. W. C. Lee; by Prof. David C. Humphreys, C. E., Washington and Lee University, Lexington, Va. 1894. 184 pages, 9 x 12 inches, autolithograph. Illustrated. Price $4.00, post-paid.

A translation of Rankine's monumental works into the vernacular, such as would render their many obscure passages intelligible to engineers, has been a desideratum ever since their appearance. The author and his two predecessors have not attempted this, but have confined themselves to the task of elucidating those comparatively few portions which might be expected to present difficulties to students. Thus we find no explanation of the following passages on pages 673 and 674:

> The Total Head of a given particle of water is found by adding together the following quantities:
>
> The head of pressure, or intensity of the pressure exerted by the particle, expressed in feet of water.
>
> The head of elevation, or actual height of the particle above some fixed or "datum" level.
>
> In order to acquire velocity from a state of rest, or an increase of velocity, a fluid particle must pass from a place of greater total head to a place of less total head. This it may do either by actual descent from a higher to a lower level, or by passing from a place of more intense pressure to a place of less intense pressure, or by both those changes combined.

From this circumstance we judge that the student finds these passages as plain as day, without a diagram.

The author has devoted to his task a vast amount of intelligent labor, not only in the preparation of the text, but in that of the very numerous and excellent illustrations, which are far superior, in point of intelligibility, to those in Rankine's work itself.

The Notes were prepared primarily for use in the author's classes, but they will undoubtedly prove of great value to other students of Rankine.

Machine Design. NOTES ON ——. By Prof. Charles H. BENJAMIN, Case School of Applied Science, Cleveland, Ohio. Pamphlet, 74 pages, 5 by 9 inches.

In the Library for May, 1894, we noticed the author's notes on Heat and Steam. The present volume is uniform with the preceding and similar in the scope of its purpose, which is, "to gather together in small compass the more simple formulas for the strength and stiffness of machine parts, with an explanation of the principles involved, and with such tables and information as the designer of machinery might find useful,—to put the mathematical principles of machine design in a compact form, at a moderate price, for the use of the student and the young engineer." The English system of weights and measures is adhered to, and

the book is interleaved with blank pages for the convenience of the student. The various propositions are fully and satisfactorily, although not very artistically, illustrated.

Elementary Principles of Mechanics. Vol. II. Statics. By A. Jay Du Bois, C. E, Ph.D., Professor of Civil Engineering in the Sheffield Scientific School of Yale University. First edition. First thousand. New York: John Wiley & Sons, 1894. Cloth, $4.00. 392 pages.

In the Library for October we noticed the appearance of the first volume of this work, viz.: Kinematics, and the remarks there made apply with full force to this second volume of the series, not the least important feature of which is the very large number of examples by which the propositions are illustrated, and which are worked out in the text.

Aërial Navigation; Proceedings of the International Congress of—, held in Chicago, August 1, 2, 3 and 4, 1893. *The American Engineer and Railroad Journal.* New York, 1894. 414 pages and Index. $5\frac{3}{4} \times 8\frac{1}{2}$. Price $2.50.

In the Library for July, 1894, we noticed, at considerable length, Mr. O. Chanute's monumental work upon Progress in Flying Machines. The present volume appears under the auspices of the same publishers, and, unfortunately, in the same fine and closely-set type.

This notable conference was opened by Mr. Chanute, Chairman of the Organizing Committee, who presided over the first day's session, at which the scientific principles of aërial navigation were discussed. The amount of material presented is so great that we can here barely allude to a few of the most notable papers, as follows:

On the Internal Work of the Wind. By Prof. S. P. Langley, Secretary of the Smithsonian Institute.

On Atmospheric Gusts and on Aëroplanes and Flying Machines. By Prof. A. F. Zahm.

On the Mechanics of Flight and Aspiration. By A. M. Wellington. (A paper discussed by Messrs. J. Bretonnière and H. A. Hazen.)

On a Theory of Sailing Flight, on Aëroplanes and Flapping Machines, and a Note on the Elastic Screw. By William Kress, of Vienna.

Flying Machines, Motors and Cellular Kites. By Lawrence Hargrave, the noted experimenter, of Sydney, New South Wales.

On Flotation *versus* Aviation. By Prof. DeVolson Wood.

On Systematic Explorations of the Upper Air, with Estimates of Cost. By Mark W. Harrington, Chief of Weather Bureau, Washington, D. C.

On Scientific Results Gained by Balloons, and Ten Miles Above the Earth. By H. A. Hazen, of the Weather Bureau.

Also four papers by Carl E. Myers, whose name is followed by the novel title of Aëronautical Engineer.

Prof. Thurston contributes Notes on the Materials of Aëronautic Engineering, and C. E. Duryea, of Peoria, Ill., one with the significant title "Learning How to Fly."

Les Réformes des Tarifs de Voyageurs. By L. de Perl, Counsellor of State, Director of International Service of Russian Railways. Published by order and under the auspices of the Russian Ministry of Finance. Paris: J. Rothschild. 1893. 279 pages.

The author's instructions from the Russian Minister of Finance contemplated the study of the reform of passenger tariffs adopted by the Hungarian Government,

with a view to ascertain its applicability to the Russian railways; but, in pursuing these studies, the author became convinced that an examination of the Hungarian system alone would not suffice for arriving at a proper view of the main question, and he has therefore extended his investigations to the systems in vogue in other European countries.

In the first chapter the author reviews the history of reform in passenger rates, beginning with the project of William Galt in England, in 1843, following close upon the reform of postal charges introduced by Rowland Hill in 1840, reforms which give to England the credit of pioneership in both directions.

The systems inaugurated in the several European countries are then examined and discussed in detail, and the author sums up his conclusions, in which he recommends the adoption of the differential tariff in preference to the Zone system, and proposes a tariff affecting material reductions in existing rates, the reductions increasing as the distance traveled increases.

U. S. Department of Agriculture.—Office of Road Inquiry. Bulletins 1–8.

No. 1 is a valuable compilation, by General Roy Stone, Special Agent in Charge of Road Inquiry, of State Laws relating to the management of roads, enacted from 1888 to 1893. Fourteen States are here represented, and the laws given are nearly all of the year 1893, although New Jersey, the pioneer State in the matter of new road laws, began enacting them as early as 1888.

No. 2, Proceedings of the Minnesota Good Roads Convention, held at St. Paul, Minn., January 25 and 26, 1894.

No. 3, The Improvement of the Road System of Georgia, by O. H. Sheffield, C. E., with an illustrated description of the methods employed.

No. 4 is a report on Road-Making Materials in Arkansas, by John C. Branner, State Geologist.

Nos. 5, 6 and 7 give Information regarding Road Materials and Transportation Rates in certain States west of the Mississippi River, north of the Ohio River, and in the eastern and southern sections, respectively.

No. 8, The Construction and Repair of Earth Roads, by General Stone.

No. 9, State Aid to Road-Building in New Jersey, by Edward Burrough, Chairman of the New Jersey State Board of Agriculture and State Commissioner of Public Roads.

Building for Library of Congress.—Report upon the Construction of the —— during the year ending December 1, 1894.

The two photographic views here shown, one taken from the dome of the Capitol and the other from near the southwest corner of the Library building, both taken on November 20, 1894, show that the latter was at that time nearing completion. The last stone of the superstructure was laid on July 7th, and the last of the walls of the building proper was thus completed. At the date of the report, December 3d, operations were still actively progressing, some 400 workmen being steadily employed. It is confidently stated that in the event of sufficient appropriations the building will be finished early in 1897, and that the total cost will be within the limit fixed by law. Over four million dollars have already been expended. Mr. Bernard R. Green, C. E., Member American Society Civil Engineers, is in charge of the work.

The report contains a plan for a tunnel to connect the Library building with the Capitol. The tunnel will contain a cable for the rapid transmission of books,

etc., between the two buildings, and a small pneumatic tube for the transmission of written messages, telephone wires, etc. It is said that the cost of the tunnel and apparatus complete will not exceed $35,000.

Washington Aqueduct; Annual Report upon the—, Increasing Water Supply of the City of Washington, and Erection of Fish Ways at the Great Falls of the Potomac, in charge of George H. Elliot, Colonel Corps Engineers, U. S. A. Washington, 1895.

In discussing the Washington aqueduct, Colonel Elliot takes up the subject of filtration of the city's water supply, and, after considering the claims of mechanical or rapid, and of natural or slow, filtration, he reaches the conclusion that there appears to be no cause for apprehension respecting the healthfulness of Potomac water as delivered by the river into the intake of the aqueduct at Great Falls; and that, as long as the present condition continues, the great expenditures that would be required for the first cost of filtration works and for the annual cost of their maintenance would not be justifiable, and that for the present, at least, reliance should be had on sedimentation.

California State Mining Bureau.—Twelfth Report of the State Mineralogist. Sacramento, 1894.

Although the act of the California Legislature providing for the establishment of the State Mining Bureau was not approved until March 23, 1893, the bureau has already shown marked activity, as witness the second biennial report of the State Mineralogist now before us. This constitutes a veritable mineralogical and geological description of the State, the principal products being treated in alphabetical order. Naturally gold monopolizes some 250 pages, or nearly one half of the entire volume, but structural materials, and notably granite and other building stones come in for extensive mention. The volume is handsomely illustrated by photographic and other views, some of which present remarkably striking scenic features. Mr. Thomas Haight Leggett contributes an elaborately illustrated paper of forty-one pages on the Use of Electric Power Transmission Plants in Mining Operations, and the report closes with geological notices of certain of the counties of the State, and an appendix containing various acts of legislature bearing upon the mineral industries of the State. In addition to the preparation of its reports, the bureau issues, from time to time, bulletins, one of which, by Mr. W. H. Storms, on Methods of Mine Timbering, was briefly noticed in the Library for August, 1894.

Society Proceedings.

American Society of Civil Engineers, Transactions of the ——. December, 1894, Vol. XXXII, No. 6.

The prominent feature of this number is an elaborate and handsomely illustrated paper by Mr. John Thomson, describing the Platen Process for Letter-Press Printing, etc. Mr. Bolton W. DeCourcy contributes an account of the Improvement of Gray's Harbor, Wash., and Prof. Mansfield Merriman discusses, in an illustrated paper, the Strength and Weathering Qualities of Roofing Slates.

Federated Institution of Mining Engineers, Transactions of the ——. Vol. VIII, No. 1. Issued November 24, 1894. Newcastle-upon-Tyne. Price 12s.

In the Contribution Box for January, 1895, we gave a brief account of this Institution, which, like our own Association, secures co-operation among a number of engineering societies for the benefit of all.

We now receive from the Secretary a copy of these Transactions, which we may with profit compare with our own JOURNAL.

We note, in the first place, that the price of this one issue, with its 224 pages, is the same as our subscription price for our annual volume, which now contains about 1,000 pages of reading matter and index.

We note, further, that, notwithstanding the improvement which has been effected in the appearance of our JOURNAL, this British publication is still, in many respects, decidedly superior to our own, but we may trust that when our subscription rate has been quadrupled we may appear in as handsome shape.

As might be expected from the title of the Institution, the papers presented bear almost exclusively upon matters of interest to mining engineers, but Mr. Morgan W. Davies contributes a paper, illustrated by four plates, upon timber bridges and viaducts.

The gas tester for detecting and estimating fire-damp in mines, invented by Thomas Shaw, of Philadelphia, is described and illustrated by Mr. Joseph R. Wilson, member of the American Institute of Mining Engineers.

Editors reprinting articles from this journal are requested to credit both the JOURNAL and the Society before which such articles were read.

ASSOCIATION OF ENGINEERING SOCIETIES.

Organized 1881.

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THE CHICAGO SANITARY DISTRICT CANAL.

I. Introductory.

BY ISHAM RANDOLPH, MEMBER OF THE WESTERN SOCIETY OF ENGINEERS.

[Read August 1, 1894.*]

I APPEAR before you to-night in fulfillment of a promise made to our worthy Secretary some weeks ago, that I would prepare and present at this time a paper upon the work of the Sanitary District of Chicago which should be the introduction to a series of papers to be prepared by the Engineers directly in charge of the several Divisions, descriptive of the methods pursued and the results accomplished upon the sections under their direction. The promise was a rash one, and I now know that I should not have made it.

When a work of this magnitude is being crowded forward, it demands the entire time and the best thought of its executive head. This being true, I find that in making the promise to which I stand committed I have done myself an injustice no less than the enterprise of which I have undertaken to treat, besides the still further wrong of disappointing an audience which I would fain please, if I cannot instruct. With this introduction and apology, I will proceed at once to the subject in hand.

The Sanitary District of Chicago comprises practically all of the city north of 87th Street, and about forty-three square miles of Cook

* Manuscript received March 11, 1895.—*Secretary, Assn. Eng. Socs.*

County outside and west of the city limits. It would be interesting to introduce here a few pages of history; to review the causes which, year by year, with the growth of this mighty city, have gathered force and unity until they have compelled action.

A review of the various projects proposed for relieving Chicago of its incubus of filth, and a presentation of the arguments put forward by the advocates of each project, would afford subject-matter both instructive and entertaining; but it is not for me to take up the bygones. The issues have been joined, and one of the theories of yesterday is passing rapidly to-day into the fact accomplished.

The Sanitary District of Chicago was organized under the law for incorporating Sanitary Districts, enacted by the Legislature of the State of Illinois in 1889, approved May 30th, and in force July 1st, 1889. It is entirely separate and distinct from the municipal government of Chicago. Under the general law above referred to, the Trustees may levy and collect taxes for carrying on the work intrusted to them, to the extent of one-half of one per cent. per annum of the value of the taxable property within the corporate limits of the District, as the same shall be assessed and equalized for State and County taxes of the year in which the levy is made. They may issue bonds to the extent of 5 per cent. of the value of the taxable property of the District, as determined by the last assessment for State and County taxes previous to the issue of said bonds; provided, however, that said 5 per cent. shall not exceed the sum of $15,000,000. The population of the District is now about 1,400,000, and the assessed vulue of the property is $242,-438,000.

The District organization constitutes probably the most independent civil corporation extant. The Trustees, nine in number, are elected by the voters of the District, and hold office for a term of five years. They take their commissions from the people and are answerable to the people only. They elect one of their own number President, and the term of office is one year. The officers, other than Trustees, are a Clerk, Treasurer, Chief Engineer and Attorney, each with an appropriate staff of assistants.

The first Board of Trustees was elected November, 1889, and their first meeting for organization was on January 18, 1890, in Judge Drigg's Court Room, in the County Court House in this city. Trustees-elect John J. Altpeter, A. P. Gilmore, John A. King, Murray Nelson, Richard Pendergast, W. H. Russell, Frank Wenter and H. J. Willing were present, and Trustee-elect Christoph Hotz was absent. On that occasion a temporary organization was effected, which was followed by a perfected organization on February 15th of the same year, when the "Rules and Order of Business of the Board of Trustees" were adopted

and officers elected. The law which conferred their powers and responsibilities upon them, prescribed, in the following language, how they should construct the channel:

"If any channel is constructed under the provisions hereof by means of which any of the waters of Lake Michigan shall be caused to pass into the Desplaines or Illinois River, such channel shall be constructed of sufficient size and capacity to produce and maintain at all times a continuous flow of not less than 300,000 cubic feet of water per minute, and to be of a depth of not less than fourteen feet, and a current not exceeding three miles per hour, and if any portion of any such channel shall be cut through a territory with a rocky stratum where such rocky stratum is above a grade sufficient to produce a depth of water from Lake Michigan of not less than eighteen feet, such portion of said channel shall have double the flowing capacity above provided for, and a width of not less than one hundred and sixty feet at the bottom capable of producing a depth of not less than eighteen feet of water. If the population of the district draining into such channel shall at any time exceed 1,500,000, such channel shall be made and kept of such size and in such condition that it will produce and maintain at all times a continuous flow of not less than 20,000 cubic feet of water per minute for each 100,000 of the population of such district, at a current of not more than three miles per hour, and if at any time the general government shall improve the Desplaines or Illinois Rivers, so that the same shall be capable of receiving a flow of 600,000 cubic feet of water per minute, or more, from said channel, and shall provide for the payment of all damages which any extra flow above 300,000 cubic feet of water per minute from such channel may cause to private property so as to save harmless the said district from all liability therefrom, then such sanitary district shall within one year thereafter, enlarge the entire channel leading into said Desplaines or Illinois Rivers from said district to a sufficient size and capacity to produce and maintain a continuous flow throughout the same of not less than 600,000 cubic feet of water per minute, with a current of not more than three miles per hour, and such channel shall be constructed upon such grade as to be capable of producing a depth of water not less than eighteen feet throughout said channel, and shall have a width of not less than one hundred and sixty feet at the bottom, in case a channel is constructed in the Desplaines River as contemplated in this section, it shall be carried down the slope between Lockport and Joliet, to the pool commonly known as the upper basin, of sufficient width and depth to carry off the water the channel shall bring down from above. The district constructing a channel to carry water from Lake Michigan of any amount authorized by this act, may correct, modify and remove obstructions in the Des-

plaines and Illinois Rivers wherever it shall be necessary so to do to prevent overflow or damage along said river, and shall remove the dams at Henry and Copperas Creeks, in the Illinois River, before any water shall be turned into the said channel. And the Canal Commissioners, if they shall find at any time that an additional supply of water has been added to either of said rivers, by any drainage district or districts, to maintain a depth of not less than six feet from any dam owned by the State, to and into the first lock of the Illinois and Michigan Canal at La Salle, without the aid of any such dam, at low water, then it shall be the duty of said Canal Commissioners to cause such dam or dams to be removed. This act shall not be construed to authorize the injury or destruction of existing water-power rights.

"Control of channel when completed: When such channel shall be completed, and the water turned therein, to the amount of 300,000 cubic feet of water per minute, the same is hereby declared a navigable stream, and whenever the general government shall improve the Desplaines and Illinois Rivers for navigation, to connect with this channel, said general government shall have full control over the same for navigation puposes, but not to interfere with its control for sanitary or drainage purposes."

The carrying out of these requirements being an engineering work, a Chief Engineer was elected at the first meeting of the Board after permanent organization had been effected, and his duties, as set forth in the rules, were as follows: "The Chief Engineer shall have charge of all engineering work and shall do all surveying and civil engineering necessary or ordered by the Board; make all plans, estimates, drawings, figures and reports required by the Board; and shall perform such other duties as may be imposed upon him from time to time by ordinances or resolutions of the Board." On February 8th, Mr. L. E. Cooley, the Chief Engineer elect, reported to the board, "that all of the work preliminary to actual work of construction would require until the Spring of 1892." For several months the Chief Engineer seems to have constituted the engineering department, for while he was authorized to "secure and have in readiness" "a sufficient staff to do all of the engineering work," yet the decree recited further, "compensation of services not to commence until ordered by this board." In explanation of this a quotation from the proceedings of February 1st, suffices: "Resolved, that the officers selected shall not be entitled to draw salaries until after the Supreme Court shall have affirmed the validity of the law."

On June 14, 1890, at the eighteenth regular meeting, President Nelson called the meeting to order and spoke as follows: "Gentlemen, we now have the decision of the Supreme Court. There is nothing in the way to prevent our going ahead as rapidly as possible." At this

meeting Mr. Wm. M. Reese was appointed Chief Assistant to the Chief Engineer, and Messrs. Thomas T. Johnston and Wm. T. Blunt Principal Assistants, and we may conclude that the active work of the engineering department dated from that time. You have heard that the course of true love never did run smooth, and the same assertion applies to the courses of the Chief Engineers of this District. With active work came active opposition to the Chief Executive of the Engineering Department, and, to quote his own description of the disaster on the 10th of December, 1890, he "was thrown down stairs." You have heard of the certain resurrection of truth crushed to earth. Well, the Chief Engineer, like truth, rose again and was bidden by the people to take a place among the trustees as the peer of those who had helped him down stairs on the memorable 10th of December. He was succeeded by Mr. W. E. Worthen, who was elected on December 17, 1890, and had associated with him, as consulting engineer, General John Newton. These gentlemen remained with the District until April 21, 1891, when they resigned. On May 9, 1891, Mr. Samuel G. Artingstall was elected Chief Engineer and he held the office until January 16, 1892. His successor, Mr. Benezette Williams, was elected on the day of his retirement. Mr. Williams' incumbency of the office lasted until June 8, 1893, and since that date I have had the honor of being Chief of the Department. So much for the chronology of office-holding. It is not in order now to discuss the various routes proposed for the Main Drainage Channel nor to review the arguments advanced in favor of each, as we are dealing with the channel upon the route finally adopted and made irrevocable by the purchase of a right of way costing nearly $2,603,228, and the execution of contracts, covering 28 miles of construction, which are now being pushed forward with a rapidity unexcelled, if ever equalled, in the history of any engineering enterprise. This location is essentially parallel with the line of the Illinois and Michigan Canal. Although minor defects in alignment have been avoided, lighter curves used and longer tangents secured, the maximum curvature is 0° 36′. That portion of the route southwesterly from Willow Springs was first adopted and put under contract. The work was divided into sections averaging about one mile each, and these were numbered consecutively from 1 to 14, No. 1 commencing at the Willow Springs Road. It being considered that these were the most difficult sections, because eight of the fourteen were practically through rock cuts, and the other six were underlaid with solid rock which would form a large percentage of the entire volume, these sections were first advertised for contract, and the contracts were awarded in July, 1892. On September 3, 1892, which passed into the annals of the enterprise as "shovel day," the work was officially inaugurated in the presence of

a large company assembled on each side of the line between Cook and Will Counties, where it is crossed by the channel. President Frank Wenter wielded the official nickle-plated shovel which turned the first sod, and Trustee L. E. Cooley manipulated the battery which discharged the first blast. Speeches were made by officers of the District and by distinguished guests, and the great enterprise was fairly launched.

Easterly from Willow Springs Road, the sections are lettered from A to O, omitting J, and are entirely in "glacial drift" except for a few hundred feet on each side of the Summit Road, in sections E and F, where test-pits indicate rock rising about seven feet above the grade line at the highest point. The lettered sections are now all under contract. Sections A to F were awarded late in 1892 and early in 1893. G to M inclusive were awarded in December, 1893, and N and O in May, 1894. The cross-section finally adopted for all of the numbered sections, which will be partially or wholly in rock, is 160 feet wide at bottom and 162 feet wide at top. The sides in rock are cut vertically by channeling machines, and three stopes are prescribed, with off-sets of six inches for each stope to admit of using the channeler. The numbered sections, which are partially in earth and partially in rock, are to be walled above the rock to an elevation of 5 feet above Chicago Datum. To build these retaining walls on these sections, nearly 300,000 cubic yards of masonry will be required. The original specifications for this masonry contemplated dry rubble. The developements on the rock sections convinced me that rock to fit the specifications could not be had from the excavations, and I prevailed upon the Board to adopt cement masonry specifications. These specifications provide for the use of mortar made of cement and sand in equal parts.

The earth sections are to be 202 feet at bottom, with side slopes of 2 feet horizontal to 1 foot vertical. The earth sections, east of the range line near Summit, are not being excavated to full width. The bottom width of present excavation is only 102 feet, side slopes two to one. The reason for this is that the future enlargement can be economically made by dredging, and a present saving is effected by reducing the acreage necessary to be purchased for spoil area.

The grade throughout the lettered sections is 1 foot in 40,000 feet (0.025 per 100), and the bottom of the channel at Robey Street is 24.448 feet below datum. The grade in the numbered sections is 1 foot in 20,000 feet (0.05 per 1000).

The specifications under which this work has been contracted for, provide for but two classifications, Glacial Drift and Solid Rock. Glacial Drift is a drag net which catches everything but solid rock. The definition reads thus: "Glacial Drift shall comprise the top soil, earth,

muck, sand, gravel, clay, hard pan, boulders, fragmentary rock displaced from its original bed, and any other material that overlies the solid rock."

Solid Rock is defined in the following terms: "Solid Rock shall comprise all rock found in its original bed, even though it may be so loosened from the adjacent underlying rock that it can be removed without blasting."

The bids for Section No. 15 are to be opened on the 22d of August. This is the extreme southerly section of the channel, and on it will be located the controlling works. The design of these works is to control the discharge from the main channel into the tail race. When the flow is normal, the crest of the discharge over the waste weirs will be about eight feet below Chicago Datum, but, under conditions which may obtain, the flow will have to be shut off and the water held up to lake level, which may reach five (5) feet above datum. This section, as will be seen by an examination of the plat, fans out to a width of 505 feet. This peculiar shape does not accord with my personal views of what should be done on this section, and I am hopeful of being able, before the work progresses too far, to recast the plan upon lines which seem to me better suited to the conditions which must obtain. Our contracts provide for changes of plan during the progress of the work.

While Section No. 15 ends the Main Drainage Channel, it does not mark the southerly limit of work to be done by the Sanitary District. This work consists in preparing a tail race to receive the outflow from the channel, or practically a correction and enlargement of the Des plaines River Channel for a distance of about nine thousand feet, a work the estimated cost of which is $425,260. In addition to this, quite a large amount of work has to be done in making the channel through the city of Joliet adequate to the passage of 600,000 cubic feet of water per minute, additional to the flow of the Desplaines proper; then, too, the removal of the dams in the Illinois River, at Henry and at Copperas Creek, is made obligatory under the law.

So far I have made no mention of a most important auxiliary work which was accomplished last season. I mean the diversion of the Desplaines River. For long distances the location of the main channel occupied the bed of the Desplaines, and almost its entire length was subject to inundation during flood seasons. It is readily understood, therefore, that plans for diverting this stream had to be carried to completion before the work on the main channel could be prosecuted successfully. This work came under the head of the River Diversion Channel. About 13 miles of new channel had to be excavated. The width of cross-section adopted was 200 feet. Levees had to be constructed from the high ground below Riverside through to Romeo, a

distance of about 19 miles. A small portion of this levee still remains unfinished, but this season will see a decree of complete divorce between the waters of the Desplaines and the Main Drainage Channel in the shape of permanent barriers. At the head of this diversion it was necessary to provide a safety valve in the shape of a spillway to allow surplus water to flow toward Chicago, because arrangements have not been perfected for carrying the entire flood waters of the Desplaines through Joliet. This spillway is a concrete dam capped with cut stone, and its wings are faced with stone masonry. It is 397 feet long, and its crest is 16.25 feet above Chicago Datum. No water flows over this dam until the volume passing the water gauge above it exceeds 300,000 cubic feet per minute. The benefit, to Chicago, of this defense against Desplaines floods is incalculable. The entire cost of the River Diversion Improvement will closely approximate $1,000,000.

The bridging on this work presents no serious problems on the rock sections. On these we shall use the ordinary draw bridge with unequal arms, the shorter one counter-weighted; the pivot-pier to be on one side of the channel, which will thus be left free and unobstructed. On the earth sections the pivot piers must be placed in mid-channel, and, inasmuch as the clear water-way on each side will probably be 110 feet, it will be seen that where the angle of crossing is necessarily acute, as in the case of one or two of the railroads, a very long bridge will be involved. One such bridge, which we have under advisement, will be 480 feet over all. A six-track bridge will be required where we cross the tracks of the Panhandle, Stock Yards, and Northern Pacific Railroads. For this situation I am hopeful that a leaf or folding bridge can be successfully designed and used. We are now wrestling with several railroad problems of great importance to us and to the other parties in interest, but the discussion of these at this time would be premature.

The tabulated statements accompanying the report of the Superintendent of Construction, Mr. U. W. Weston, for the month of June, are both interesting and instructive, as showing the progress made throughout the work.

Progress is rated upon a money basis. The estimated cost of each section is divided by the number of months allotted for its performance. Rating by yardage, that is, dividing the total yardage by months allotted for doing the work, would be giving equal periods for moving equal volumes of the cheap tractable and the costly intractable materials, whereas the money rating makes the more rapid movement of the tractable materials imperative.

A condensed statement, showing the magnitude of the work, will not be out of place here.

MAIN CHANNEL.

Glacial Drift	26,421,186	cubic yards.
Solid Rock	11,775,404	" "
Retaining Walls	304,734	" "

RIVER DIVERSION.

Glacial Drift	1,658,384	cubic yards.
Solid Rock	260,561	" "

MAIN CHANNEL AND RIVER DIVERSION COMBINED.

Glacial Drift	28,079,570	cubic yards.
Solid Rock	12,035,965	" "
Total Excavation	40,115,535	" "

TOTAL COST, AS PER REVISED ESTIMATES.

Construction Account	$20,377,048 40
Right of Way	2,603,227 92
	$22,980,276 32

This estimate is entirely exclusive of engineering and other administrative expenses.

With this introduction I will leave the field clear to my co-workers who will from time to time present this Society with papers relating to the work under their control, giving descriptions in detail of the several mechanical devices used, with statements showing their efficiency, as proven by the work accomplished. We may also expect contributions to the stock of knowledge relating to the flow of water in open channels over dams, etc., deduced from observations and flood measurements extending over long periods and made under varying conditions by our hydraulic engineers.

My prologue ends here. Should it be my privilege to carry this great work to completion, I shall feel a pardonable pride then in asking you to listen to the epilogue.

THE USE OF STEEL IN LARGE BUILDINGS.

By Corydon T. Purdy, Member of the Western Society of Engineers and of the American Society of Civil Engineers.

[Read before the Boston Society of Civil Engineers, January 23, 1895.*]

The use of steel in the construction of large buildings has opened a new and extensive field for the work of engineers, but its value to the profession is only gradually being realized.

Such buildings, as a whole, have attracted attention more than has the use of the steel in their construction. The one can be criticised more easily than the other. When a building is finished it stands exposed to public view, with all its advantages and its faults, while the steel used in its construction is covered up quickly and is as quickly forgotten by the majority of men. It may be good or bad, no one knows the difference; and so, some of the most wonderful things about great buildings, their frames, the great power plants that throb day and

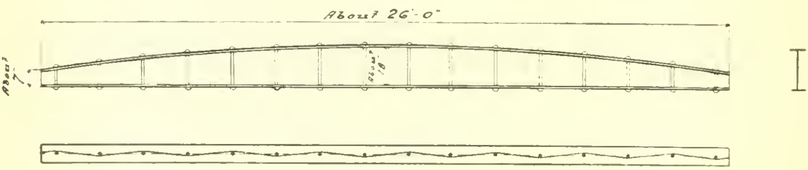

Fig. 1.

night somewhere beneath them, and much of their hidden mechanism, is comparatively unknown.

It would be very difficult to determine exactly when and how iron was first used in the construction of buildings. Cast-iron columns and lintels have been in use, of course, for many years, but the substitution of wrought iron and steel and the introduction of the present methods of their use are comparatively recent. Indeed, there are few things even in this progressive age of ours, which have developed and improved as rapidly as the use of structural metals. This is true in its application to bridges and buildings, and to all other forms of construction. Some of the most common adaptations and combinations of rolled iron were not thought of forty or fifty years ago, as can be clearly shown by the comparison of present types with almost any old ones that can be found. There is an excellent illustration of this in some iron girders (Fig. 1) which were removed from Sedgwick Hall at Lenox, Mass., a

* Manuscript received February 22, 1895.—*Secretary, Ass'n. Eng. Socs.*

few years ago. They were each made of three plates, a top and a bottom one, both horizontal, with a vertical corrugated web plate between, the corrugations running up and down. The three pieces were fastened together with vertical bolts extending through the top and bottom plates, about 20 inches apart, and alternating, one on this side and the next on the other side of the vertical plate, the transmission of strains from the web to the flange depending entirely upon friction. These beams were probably placed in position about 1840, and some of them still remain in the building. The designer evidently understood that more metal was required at the top and bottom of the beam than in the center, but did not understand the relation of shear and bending stresses and the necessity of a proper connection between the web and the flanges.

The first iron beams made in this country were rolled at Trenton, N. J., in 1853, and the first steel beams produced in this country were manufactured by Carnegie, as late as 1885.

The modern building constructed with a steel skeleton frame is quite a different thing from the building of twenty or even ten years ago. In the old buildings, beams and columns were an adjunct to the masonry work; in the new ones the relation is reversed. The masonry walls are not needed for their strength. In the very modern buildings they are cut into small parts and carried on the steel frame. Their exterior appearance is, therefore, entirely deceptive. In the old buildings, iron, when used at all, was used in disjointed and disconnected pieces, the various parts having little relation to, or dependence on, each other; while in the new buildings, the steel frame is a unit—a complete whole—the members of which are closely related to each other and dependent on each other. In the old buildings the structural metal was comparatively an unimportant item, while now it is the most important one. The words "old" and "new" are used here as referring to the two types of construction—the one dependent entirely upon its masonry for support, and the other dependent entirely upon the iron for support—rather than to time; for it must be borne in mind that both types of construction, as well as every possible combination of the different features of the two types, are now being employed everywhere in this country. Indeed, now that the value of the steel frame is becoming established, it seems as if every possible eccentricity and absurdity is pushing itself forward for recognition.

The most important difference, however, between old and new buildings, is in the construction of exterior walls, which, in the typical building, are entirely supported from floor to floor on the steel frame. This, however, gives rise to two other marked differences. As the walls in the new buildings are supported at every floor, the window areas may

be made very much greater, and, as the walls carry no load, they may be made thinner—16 inches being ample in the West. This increased window area is very important in smoky cities, and the floor area gained by the thinness of the walls is important wherever great buildings are called for.

The complete support of floors upon columns makes it possible to omit heavy interior walls and to put partitions anywhere in the new buildings or to omit them entirely or to put them in and take them out at any time without really injuring the building. Still another difference relates to the foundations. As walls tend to diffuse loads and columns tend to concentrate them, the use of the latter in the new buildings renders the foundation problem more definite and thus, to some extent, more simple.

This reversal of building methods, this change about in the function and use of masonry walls, and the introduction of such new conditions in large buildings is a real revolution, the extent of which can hardly be realized.

It has gone on in the East and in the West simultaneously, but not in the same way. In both places it has been a process of evolution, but industrial interests, the building laws, and the greater conservatism of the East have tended to retard it here, while in the West industrial interests have stimulated it more than they have retarded it, and the remarkable enterprise of Chicago has made such great demands upon both architects and engineers that they have been forced to be progressive. The result is that the constructive side of the problem has reached its most perfect development in Chicago practice. This is generally true in spite of some most excellent work in the East and some very poor work in Chicago. The rapidity and history of its development can be very readily traced in that City. A new idea is tried to a limited extent in one building, a bolder application of it is attempted in the next; another idea, originating in another office, is worked out in the same way. Thus the evolution proceeds and honors are extremely hard to divide.

Mr. Jenney, Mr. Burnham and Messrs. Holabird & Roche, of Chicago, have taken the most important part in this movement. Chicago's pride is its Auditorium, designed by Messrs. Adler & Sullivan; and other notable work has been done there by other architects, but these have led the way in the use of steel. It is easy to use a method that some one else has demonstrated to be practicable—a good deal easier than to attempt an innovation, at another man's expense, amidst adverse criticism, and with one's own future in the balance, even if one feels very sure he is right. It is because these men have done so much without precedent, in just this way, that it seems as if their names ought to

be permanently linked with the introduction of the use of steel in buildings.

The differences between the eastern and western phases of this forward movement has not been due to a difference in men, however. It has been due rather to a difference in conditions, circumstances and opportunities, and, while the pioneer work has been done chiefly in the West, some of the heaviest work has been done in the East. Mr. Post, of New York City, whom Mr. Burnham called the father of big buildings, was educated as an engineer, and he is, in many ways, as closely identified with the introduction of steel as are these Western men. The East has also the greater wealth, and it is continually making greater demands on architects and engineers. Without question, the greatest engineering problems in the construction of buildings—possibly the greatest in the history of the world—will arise in these closing years of the nineteenth century, and in the eastern cities of these United States. Western architects are recognizing this fact, and they will invade the East with their work, even as Eastern men have continually found clients in the West.

The change to steel construction is forced. The classical student has no liking for it. Stone and heavy masonry have always been what they seemed to be, and honesty is one of the first principles of art. The use of steel, therefore, forces brick and stone to violate this fundamental ideal of architecture. One of our oldest New York architects recently said, "We don't like it; we don't like it, but we've got to use it." Commercial interests tend to overbalance all other considerations, East as well as West.

The need for an engineer comes in at this point. The demand for steel has grown out of its many advantages—the economy of floor area, the greater height to which buildings may be carried, the increased lighting capacity, the larger liberty in the arrangement of rooms and like considerations; but the ability to use it well depends upon other things,—upon its safety and its durability, upon a technical knowledge of strains and of the strength of materials—and these are engineering problems. The first question in the construction of a building is one of utility; then comes that of safety and economy; and with this beginning the building problem both divides and multiplies itself rapidly. Every architect who has designed a large building knows how true this is. Most of the questions do not affect the construction at all, and the architect can deal with them without the aid of an engineer. Others affect the work of construction, and yet must be finally decided by the architect. The questions, however, involving a technical knowledge of the strength of materials, shop practice and metallurgy, are purely of an engineering nature, and, so far as the architect concerns himself with

them, he is acting as an engineer. In older days, and in the design of smaller buildings, the questions concerning their strength were determined chiefly by experience and precedent and less by scientific considerations, and it is only with the advent of steel that the engineer has become a necessity. But, while these questions of strength and endurance are in general purely technical, and are entirely independent of all the other problems in the building, the final result is so closely identified with its architecture and its utility that the engineer cannot possibly succeed in producing a satisfactory design unless every feature of his work is made acceptable to all these other considerations. Indeed his success in this line of work, and his ability to lighten the labors of the architect, depend quite as largely upon his ability to appreciate what is required in the building in every way, and to anticipate the wants of the architect with whom he works, as upon his technical knowledge as an engineer. He must really be both an architect and an engineer; an architect at least so far as construction and commercial considerations are concerned.

The purely technical questions involved are practically the same in all buildings, and first among them is the question of strength, the strength of beams, the strength of columns, and the lateral strength of the building.

The strength of beams is well understood, and the formulæ which apply are mostly simple and easily handled; though many of the calculations are rendered tedious by a complicated distribution and arrangement of loads. Error is most likely to occur in the fixing of the point of maximum moment and in the application of principles or formulæ, especially in beams where the points of reaction are not well determined or where the length of the beams is to be so fixed to obtain given reactions or certain moments of resistance, as very often occurs in foundation work. It often happens that the points of maximum moment must be calculated, and it is quite possible that the maximum moment, or one almost equal to the maximum, may occur at two or more sections of a given beam. The loads which beams must carry are fixed by law in most cities, but the architect and the engineer cannot depend upon legal requirements. Beams should, of course, first of all, carry the dead load, that is, their own weight and the weight of other material actually resting upon them. Then, if the beam is in the floor, or is in any wise subject to the effect of a movable load, an appropriate allowance should be made for that. The floors of a warehouse recently designed in Chicago were made strong enough to carry 640 pounds per square foot of the tributary floor, and this was not too great. In this respect, however, building laws are sometimes needlessly burdensome. Both New York and Boston require 100 pounds on office floors, whereas

60 or 70 is quite sufficient, provided there are proper restrictions in regard to safes. The use of 16,000 pounds per square inch as the working stress of the outermost fibre is almost universal, but this must occasionally be reduced to prevent too great deflection.

The column question presents an entirely different problem. Here there is no uniformity of practice and no uniformity in legal requirements; indeed, the laws relating to the subject are more antiquated than the practice. Column formulæ are not simple, and their real values are in question. They are all founded on an exact condition of concentric loading, whereas that condition rarely exists in building work and the departure from it is often so great that a blind use of any formula would be dangerous. The results obtained under these circumstances are always unsatisfactory. The formulæ are also cumbersome, involving much tedious labor, and, in these days when work must oftentimes be done rapidly and at small cost, the loss of time and extra expense involved on this account is considerable. If a man has a hundred columns to dimension, ten minutes on each would aggregate two good days of labor, and many buildings contain five hundred or a thousand. We must provide for eccentricity of loading, and the formulæ in use are not readily adjusted to any such complication of the problem.

Prof. Johnson, of Washington University, in a recent number of *Engineering News*, deplores the many attempts made during the last few years to disprove the ordinarily accepted principles of mechanics, as applied to the strength of beams and columns. In his exact statement he is certainly right, but, so far as the formulæ in use for the calculations of columns fail to express such accepted and well proved principles of mechanics, or so far as such formulæ represent conditions which we no not deal with in practice, we certainly have a right to question their real usefulness.

We want a simple column formula which will apply under all conditions of loading, which can be used rapidly, and which will give satisfactory results. When the moment of resistance of a beam under a definite condition of loading indicates that the outermost fibre is not strained more than 16,000 pounds per square inch of section, we know definitely and exactly what factor of safety exists in the beam. We want just such definite knowledge as this about columns. Prof. Mansfield Merriman's recent paper on the "Rational Design of Columns" points directly toward this end. He states: "When the true theoretical column formula is established, it will be unnecessary to state it in a specification, but, as is now done for beams, a simple requirement like the following will be alone needed: 'The maximum unit-stress on the columns shall not exceed, for wrought iron, 8,000 pounds per square

inch, under the action of live loads, and 16,000 pounds per square inch under dead loads.'" This is a perfectly rational statement. What we want always to be sure of is, that our columns have a given factor of safety; or, in other words, that the maximum fibre strain is not greater than one-third or one-half, as the case may be, of the elastic limit of the material. But this column formula will not be valuable, even if it gives us this maximum fibre stress, unless it is so comprehensive that it will cover all conditions of loading, and all conditions and sections of columns, and unless it is so certain in its results that we can place our entire dependence upon it. Prof. Merriman has taken a long step in this direction, and his paper is well worth careful study.

Three factors enter, or should enter, into a perfect column formula, viz: the direct concentric load, the influence of flexure and the effect of eccentricity of loading or of horizontal loads. Prof. Johnson brings out these three factors in the discussion of columns in Chapter IX of his new book entitled "Modern Framed Structures," though the third element is omitted in the formula which he finally derives. The second element, that is the influence of flexure, is not nearly so important in its requirements, as the effect of eccentricity of loading, and might, possibly, be omitted from this formula, which we want for practical use in designing columns for buildings. Certainly the error would be slight within proper limitations. Prof. Merriman covers the same ground in the paper referred to. He states that "when a rational formula is established, for a long column it will reduce to Euler's expression and for a short prism it will reduce to the simple expression for pure compression." Later he shows in his table that the maximum fibre-stress under concentric loading, in columns of the dimensions in ordinary use in building work, does not exceed by more than 2 to 5 per cent. the total load divided by the section of the column in square inches. If this result be true, and it has not been questioned, we shall be safe, until we can do better, in treating ordinary columns in building work as being in direct compression, only adding always sufficient metal to provide for the eccentricity of the load.

This method is given in detail in the Chap. XXVIII. of Prof. Johnson's work, and is, in effect, as follows:

First: Find the section required for the total load, both eccentric and concentric, when treated as a concentric load.

Second: Find half the width of the column, and the radius of gyration of the section in the plane of the eccentric loading.

Third: From the equation

$$\text{Area} = \frac{\text{the bending moment} \times \text{half the width of the column}}{\text{the allowed unit-stress} \times \text{the radius of gyration squared}},$$

we find the area of section to resist the bending moment arising from whatever cause.

Fourth : If this second area can be added to the first assumed area of section, without materially changing the radius of gyration and half the width of column, it may be done, thus obtaining the total area of section without a new solution.

Fifth : If the radius of gyration and half the width of the column must be changed in order to provide sufficient area of section, or if it seems advisable to change them for economy, then a new assumed section is taken and the radius of gyration and half the width of the column found for it, and the solution proceeds as before.

The formula that we want, must be something better than this, however, for this involves the use of the radius of gyration of the column and cannot be used rapidly without a very complete table of sections with their moments of inertia and radii of gyration. Even then, its operations require too much time.

But the strength of columns does not depend entirely upon what might be called the formula considerations. The shape of the section, the number of pieces which must be riveted together to form it if made of rolled material, the amount of riveting required and its position, and especially the manner in which the different pieces are connected when they are not riveted directly to each other, are all very important elements bearing upon the strength of columns. Suppose, for example, that we have several columns of the same length, of the same sectional area, of the same material, and of the same radius of gyration, but differing in design. Thus, one might be a Gray column, another a Phoenix column, a third might be made of plates and angles. It is possible that all of these conditions might practically be fulfilled. According to all standard column formulæ they would be equally strong under a concentric load; whereas, in fact, even this is questionable while their resistances to an eccentric load are certain to be very unequal. Under direct bending, one half of the Gray column is practically neutral, and the two parts of the other half are not directly connected, while the column made of plates and angles is as well designed to resist bending as a box girder. This illustration shows two extremes. If these columns are not equal in strength under concentric loading, the inequality must be due to these considerations of form and assembling, which are therefore only second in importance to those of the theoretical formula.

The character of the material, the workmanship in the shop, and the detailing of the connections of column to column and of beams to columns are still a third class of considerations, altogether too important to be neglected.

The relative value of cast-iron and steel columns ought to have a place in this consideration, though other things beside the question of strength bear quite as pertinently on their relative value. The days in which cast-iron columns will be used in the construction of high build-

ings are fast being numbered. It would hardly seem necessary to compare them with steel columns before an audience of New England men, if we will but recall the Pemberton mill disaster, with its frightful loss of life. If cast iron is used at all, it should be in buildings of moderate size, with a very large factor of safety, with very careful designing and with the closest inspection. It is true that we have some very large buildings, both in the East and in the West, constructed with cast-iron columns; but that is no proof of their value or advantage.

Until within the last three years or so, the use of such columns had no more able supporter than Mr. Jenney of Chicago. At the last annual meeting of the American Institute of Architects he referred to the finding of an imperfection in a cast-iron column which illustrates their unreliability so well that it is worth recording in detail. It is shown in Fig. 2. He says:

"The pig iron used was excellent and satisfied all tests, and the exterior workmanship was all that could be desired. There was not a flaw or a blemish anywhere visible until the inspector applied the sound test, tapping gently over the surface with a light hammer and listening

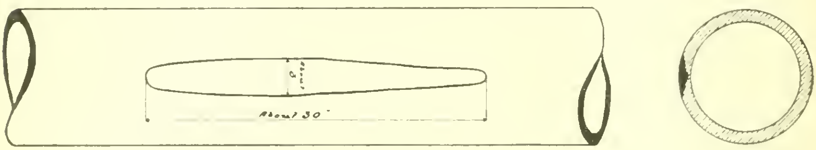

Fig. 2.

attentively for any variation in sound. At one place on the column he thought he noticed a change, extending along the column some considerable distance. Outside of this limited area the ring was clear, within it the sound was less so. He went over this repeatedly, looking for some external indication. All that he could find was a little scratch which seemed to have been made by the thumb nail in the sand of the mould, and did not in any way suggest a defect. He, however, called for a cold chisel and hammer and drove it in where this scratch appeared. Instantly there jumped out a cold shut about 30 inches long and varying from 2 to 4 inches in width. The thickness along the outer edge was scarcely more than a sixteenth of an inch, and at places even less so, while in the center it was fully $\frac{3}{4}$ inch. Both the surfaces of this cold shut, that is the under side of the piece that came out and the surface of the hollow remaining, were bright plumbago. It afterwards appeared that the plumbago, which had been used as a wash on the mould, had floated off in the iron, and, by introducing this thin film of plumbago on the interior of the melted iron, prevented a junction and formed this cold shut. Had this been on the interior of the column, which was quite as

likely to have occurred as on the outside, it would never have been detected. As it was, it would have escaped any ordinary inspection."

In this case the thickness of the metal was the same entirely around the column, but the cores in the mould are liable to be pushed out of place when the casting is made, making the metal thick on one side and thin on the other. Improper detailing may easily result in initial stresses. Flaws are as liable to occur on the inside as on the outside, where they cannot be detected, and when the column gives way, if it gives way at all, it does so without any warning.

The building laws in most large cities state the loads which columns must be made to carry. In all cases the column must carry the dead load which is tributary to it regardless of the requirements of the law. In New York City it specifies that the columns must carry all the live load from each and every floor which the floor beams are required to carry. This is excessive. It is quite possible that any given beam may be fully loaded, but it is so improbable that any column would be fully loaded that a considerable reduction might safely and wisely be made. The factor of safety for columns depends much on the use of the building. In most buildings where a proper allowance has been made for eccentricity of loads and for all other unusual conditions, a factor of two under the elastic limit of the material ought to be ample. Building laws attempt to regulate this also, but their provisions in regard to the matter differ radically in different cities and are incomplete.

Next to beams and columns the most important problem relating to the strength of a building concerns its resistance to lateral movements of any kind, whether they tend to induce a permanent deformation or are only oscillations and vibrations. It is possible that a building may sustain more or less of the latter without suffering permanent injury, but they make it unpleasant for those who occupy the building. It is especially important to guard against them in buildings the height of which is very great in proportion to the ground covered.

In any consideration of this problem we must first remember that many elements enter into it. The beam strength of a building depends entirely upon the strength of the beams, and, where there are no supporting walls, the columns are also entirely unaided in their function of carrying the weight of the building; whereas, steel bracing of any kind is assisted in its work, to some extent at least, by the weight and the condition, one or both, of all the material actually entering into the construction of the building. This makes any exact or scientific solution of the question exceedingly difficult, not particularly because of the stresses involved in the steel work, but because it is so difficult to determine the exact values of all these other factors which act in resistance to lateral deformation.

When a floor is well constructed, with floor beams and girders well connected to each other and to the columns, and with the arches, the concrete filling, and the finished floor all well made, it should act as a rigid horizontal plane, so rigid that a force applied at any point on its perimeter will be felt over its entire area, and will move it without deformation, if it moves at all. This is an important consideration. If floors are cut up by openings for stairs or elevators so that they are materially weakened, they should be strengthened with lateral rods over the tops or through the webs of the beams, to insure this rigid construction. In all high buildings this end should certainly be attained. When attained, there are two general conditions of deformation and two general ways in which lateral forces are resisted. A building may topple over as though it were a solid block, or these rigid floors may be moved over each other horizontally. Resistance to overturning depends upon the weight of the structure as a whole, and upon the area of ground covered, but the building cannot possibly overturn as a whole until the floors are so well connected and braced against horizontal lateral movement over each other, that the bracing is capable of lifting the weight of the building.

This condition can be attained in a tall, narrow steel building, but is never attained in an ordinary building. When we read of a building blown down, we read of a building that tumbles in and crushes down, but does not go over bodily.

The problem, therefore, resolves itself practically into that of so connecting and bracing the floors that they shall be able to resist this horizontal movement. The two general means for resisting lateral movements are, first, the gravity of the material and, second, lateral bracing. A wall standing alone will resist considerable wind pressure, not because of the tensile qualities of the masonry and the fact that it is braced at the ground, but because of its weight, the static condition of which must be disturbed before the wall will topple over. A large building may be built on columns—cast-iron columns, if you please—having little or no connection to each other, and the building may be completed from the second floor to its roof with the first story entirely open, with nothing except the naked columns connecting the part above with the ground below, and it will nevertheless stand a very great lateral pressure. Such a case actually occurred in Chicago, a building standing in this condition for months. This is possible, because there is a moment of resistance against toppling over, even when the base of the support is as small as the section of a cast-iron column.

This resisting moment becomes great if the weight is great. All the material in the building acts, to some extent, in this way, either directly or indirectly. The exact resisting value of a wall or a column

in this connection is a considerable problem of itself. Mr. Waite, of New York City, in a recent paper before the American Society of Civil Engineers, discussed this, giving some definite values, and his paper is well worth reading.

The other general means by which a lateral movement may be resisted, that is, by vertical bracing, concerns the strength of walls lengthwise instead of crosswise, the stiffness gained in the same way from partitions and the strength of the steel construction. In typical steel buildings, where walls are thin, light areas are large, and supports are at every floor, the lateral strength of the exterior walls, taken in this way, is not as great as that of the interior partitions, but the exact values of either are perhaps even more difficult to determine than their static resistance. The treatment of these very indefinite problems has heretofore received no rational or satisfactory solution. Even their approximate values are not to any extent agreed upon, and until they are agreed upon, we cannot know absolutely just what is required in the way of steel bracing of great buidings. Under these conditions the engineer should run no risk. If a building is without partitions, if exterior walls are thin and badly cut up, and especially if the proportions of the building are unfavorable, its lateral strength should be made secure in its steel frame.

There are three general methods of steel bracing; first, in the treatment of two adjacent columns and connecting web members of some sort, as a vertical cantilever truss fixed at the foundations; second, in the lateral stiffness of columns extending through two or more stories well spliced together at their joints, and alternating in the floors at which those joints occur; and, third, in same system of knee braces depending also upon the stiffness and strength of the connecting columns and beams and upon the manner in which they are connected. This last system is very often resorted to of necessity, where only a small bracing is desired, because it can be most easily employed without injury to the architecture or use of the building, and in spite of the fact that it is the most costly method and the most difficult to calculate properly. It is not suitable for heavy bracing,—that is for the resistance of a *considerable* lateral force, because it lacks in determinate efficiency as compared with the trussing arrangement first mentioned.

The continued columns cutting off at alternate floors have a still greater indeterminate efficiency. If they are employed throughout the building they certainly add very greatly to the stiffness of the structure, but it is very difficult to determine their value with exactness.

A fourth element of stiffness in all steel frames is the lateral strength gained in the connection of beams to beams, and more especially in that of beams to columns. The relative values of the different

methods employed in making such connections are shown to some extent in Figs. 3, 4, and 5. Fig. 3 shows the ordinary connection of beams to cast-iron columns. Fig. 4 shows one method of connecting beams to Phœnix columns. It is copied from the illustrated catalogue of Phœnix columns, published by Milliken Bros. Fig. 5 shows the connection of the beams to the Phœnix columns as designed for the Old Colony Building in Chicago. Where dependence is placed upon

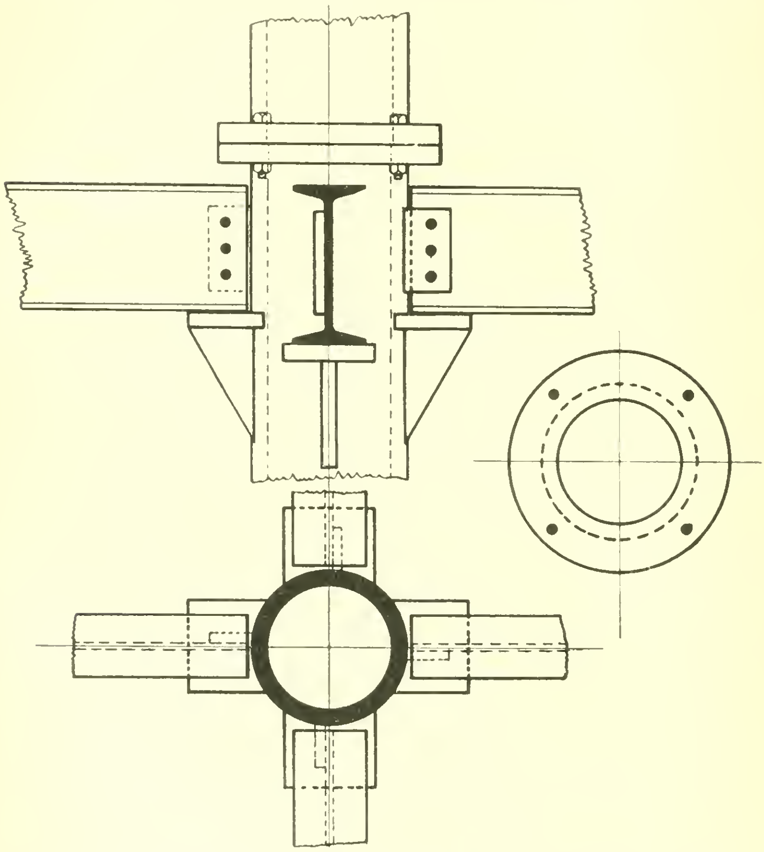

Fig. 3.—Connection between Rolled Beams and Cast-Iron Columns.

continuous columns for stiffness, the character of these latter connections has much to do with the strength of this system. Whether the columns are continuous or not, the lateral strength gained by the connection of the beams to the columns, is, of course, in proportion to the number of rivets placed in such connections, and is greatly increased by making the connection through the flange instead of through the web.

The trussing system is by all odds the most efficient, and is the one which should be resorted to in all cases where great strength is required and definiteness is desired. The position, in a building, of a vertical truss or of a system of such trusses must depend very largely upon the architecture of the building and upon its intended use. In most buildings it is difficult to find room for such trussing, and all sorts of devices have occasionally to be resorted to in order to accomplish this important

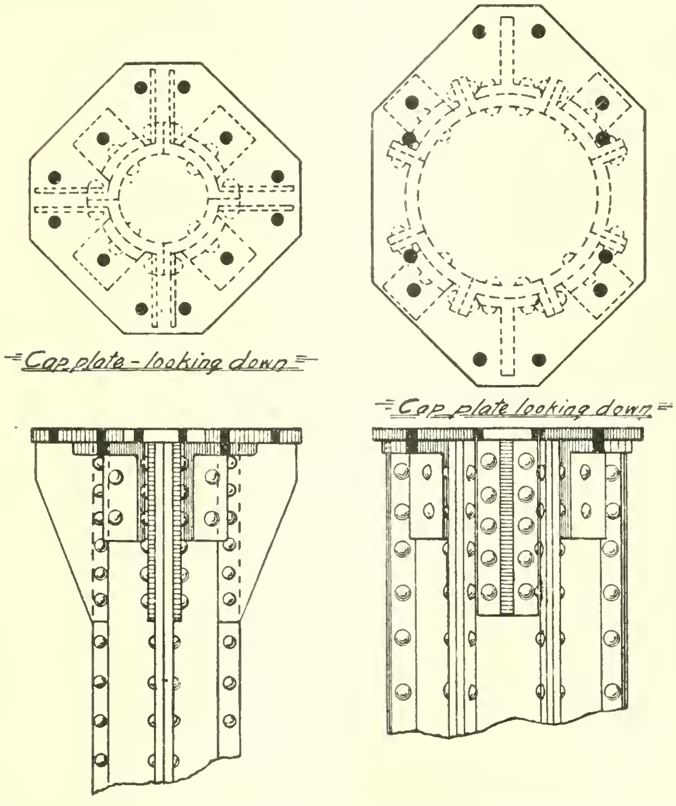

FIG. 4.—CONNECTION BETWEEN ROLLED BEAMS AND PHŒNIX COLUMNS.

end. The bracing ought to be located symmetrically with reference to exposed areas, and it ought to be so arranged that it will surely receive all lateral strains to which the rigid floors are subjected. In any truss of this kind, if we may call it by that name, the columns become the chords, one being in compression and the other in tension. The total efficiency of such a truss is measured by the dead load in the tension column, that is, the total load of all the actual material which it carries. When the tension induced by the lateral resistance of the truss is greater

than this dead load, the column joints must be connected to resist the excess and the whole must be anchored to the foundations, or the columns will be lifted and the building injured. Such connections, however, are not practicable, and the conditions requiring them should therefore not be allowed to obtain. If the lateral resistance of a truss is not sufficient for the work required without putting the column in tension, an additional line of bracing should be provided.

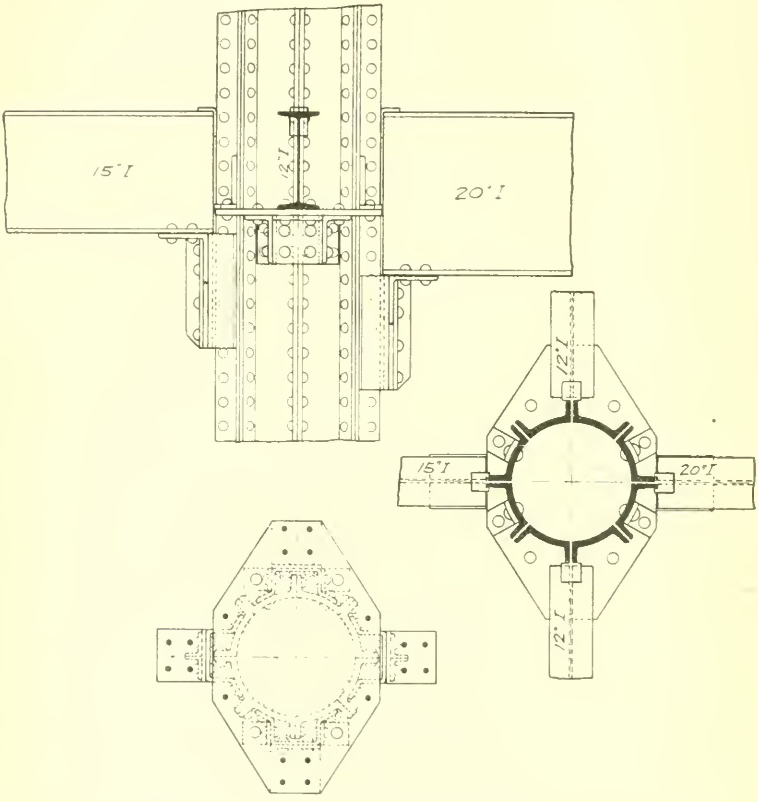

Fig. 5.—Connection between Rolled Beams and Phœnix Columns, as designed for the Old Colony Building, Chicago.

The web members of such a truss can be made in a great variety of ways, and at this particular point the engineer has a good chance to use his genius in accomplishing his purpose without really injuring the building in its architecture or in its usefulness. An intelligent architect will appreciate the need, but he is not to be blamed for insisting very tenaciously that ways and means shall be found for doing the work without interfering with the best interest of the building in other ways.

If the space between the columns chosen can be converted into a solid wall, diagonal bars, pin-connected, with horizontal compression struts, can be used. These have an advantage in taking the strains directly, and are generally easy of erection. When the space cannot be converted into a solid wall, but can be utilized, with the exception of passage ways, the diagonals may often be made to pass through two or more stories, or parts of stories, and accomplish the same result without destroying such passage ways. Steel arches, however, can be made to perform the function of a web member, and still leave a space open to connect rooms on each side, sufficient for the ordinary purposes of one room. The transmission of strains is, of course, indirect, but the arches can be designed so that all the metal will be in service, in whichever way it is strained, whereas, in any scheme of diagonal rods, a double set must be provided for the same total work, and only one of these can be in service at a time.

In a large measure this compensates for the indirectness of the strains. The arch is a riveted member throughout, and has all its connections riveted. It is therefore subject to less minor vibrations than pin-connected bracing, just as a riveted viaduct or plate girder bridge is stiffer than a pin-connected structure. In some cases where buildings are on a yielding foundation, this is a point of considerable advantage.

The difference in cost is partially made up in another way. Pin-connected members of almost any form induce a bending moment in the columns to which they attach, or require an equal weight of additional metal in their connections, while the steel arches for portal bracing can be so designed that neither of these conditions shall exist. Any design for a system of bracing of this kind should be detailed in such a way that there will be no loose joints or chances for the various members to work themselves loose in the process of time. Yielding foundations are very apt to induce initial strains in vertical bracing of any sort, and especially in truss bracing, and any liability of this sort should not be overlooked.

This entire subject of steel wind bracing is illustrated by Figs. 6 to 12 inclusive. Fig. 6 shows a system of knee braces used in the Lees Building, Chicago. This arrangement of braces extends entirely across the building, just back of the elevators and near the middle of the building. Fig. 7 shows another system of knee braces employed in the exterior walls of the Music Temple, Chicago. Fig. 8 shows bracing in the shape of lattice girders in the court walls of the Tract Society Building, New York City. Fig. 9 shows an outline elevation of the portal bracing in the Old Colony Building of Chicago. It shows two lines of portals extending from the foundations to the roof. There are two other and similar lines, the four being symmetrically arranged in the

plan of the building. Fig. 10 shows one of these portals with its connections. Fig. 11 is a photographic view of a similar portal in the D. S. Morgan Building in Buffalo. Fig. 12 shows steel bracing with diagonal bars, also in the Morgan Building.

Very much has been written about the wind forces which buildings should be made to resist, and in some respects there is considerable diversity of opinion on the subject. It is pretty definitely determined,

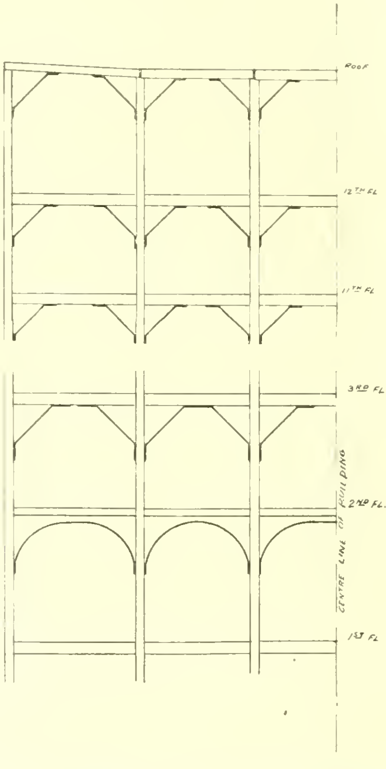

FIG. 6.—KNEE BRACING, LEES BUILDING, CHICAGO.

however, that the force of wind is usually greater at considerable heights than near the ground, though to even this there are exceptions. It is only a few years since heavy plate glass windows were blown into the bank on the second floor of the Home Insurance Building in Chicago, when lighter glass in the upper part of the building was entirely uninjured. It is also pretty well determined that a wind force of 30 pounds to the square foot is liable to occur, at not very rare intervals, in any part of the country. It seems as if we ought to be assured of resistance to 30 pounds of normal wind force per square foot over the entire side of a

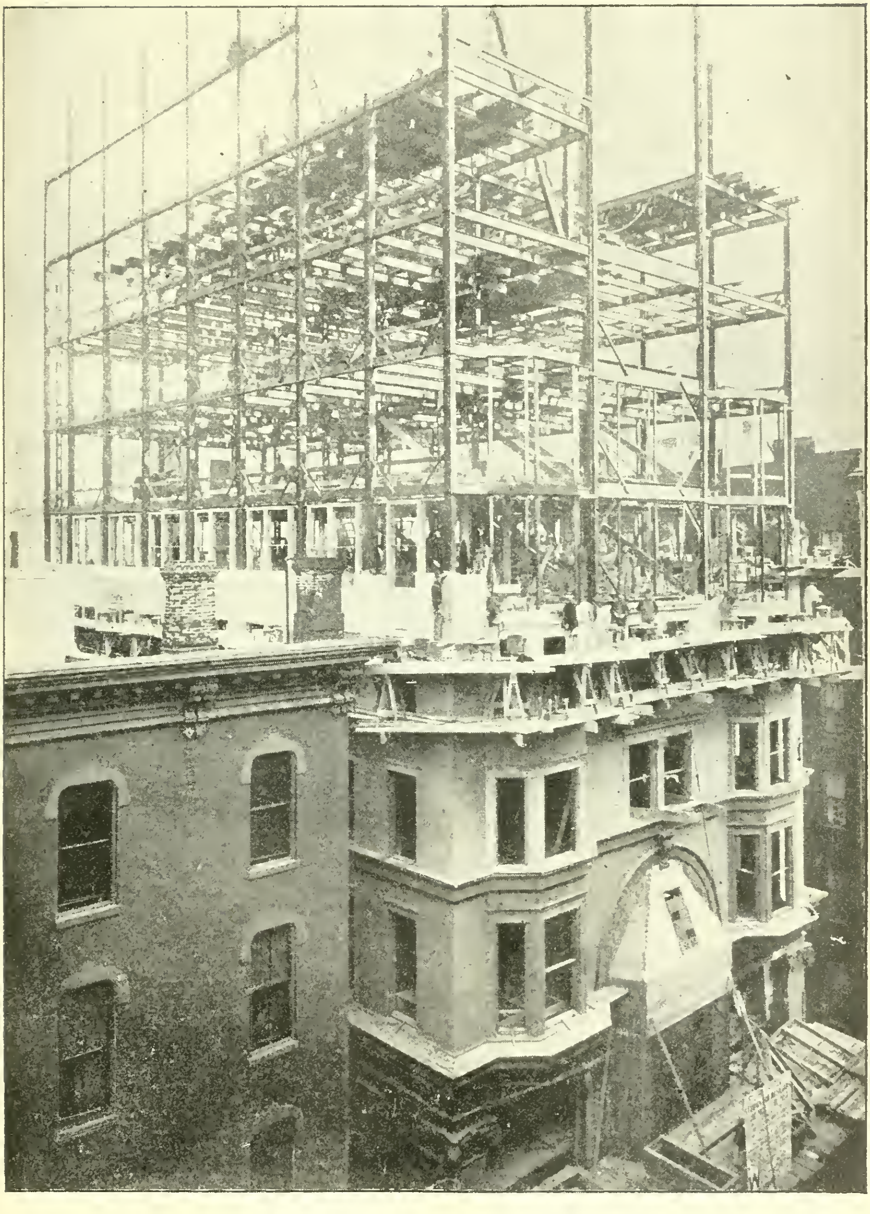

FIG. 7.—KNEE BRACING IN MUSIC TEMPLE, CHICAGO.

building, with a considerable factor of safety to cover any very unusual excess over this figure, or any defect in the material and workmanship used in the construction; and for unusual heights that this basis should not be less than 40 pounds. This requirement seems not excessive even when we consider that under ordinary circumstances such a force is exerted during only very short intervals and over small areas.

The building laws in some cities have nothing to say on this subject, and in all cities they are lacking in proper requirements. The extent to which steel should be strained in bracing depends somewhat upon the units of wind pressure used. If only the quality of the metal and the workmanship are to be considered, there seems to be no reason why 20,000 pounds per square inch in tension should not be used. No uniform

Fig. 8.—Lattice-girder Bracing, Tract Society Building, New York.

treatment of this subject is possible, for each building presents a separate problem. One of the greatest objections to the use of cast iron for columns in high buildings is its relation to this problem of lateral bracing. It is next to impossible to connect any efficient system of web members to such columns satisfactorily. The very fact that rivets cannot be used in cast iron is a sufficient objection to that material.

The efficiency of any bracing depends largely upon its absolute rigidity, and that rigidity cannot be obtained with loose bolts. The ordinary stiffness obtained in the splicing of steel columns, and in the riveted connections of beams to steel columns, is lacking when cast-iron columns are used, not only because the bolts are not as tight as the rivets; but because there are not so many of them, and because in the connection of the beams to the columns, the connection is near the

neutral axis of the beam instead of through its flanges. This is the greatest of all the objections to cast iron.

If engineers could agree upon the general principles governing the consideration of the subject, and especially if they could agree upon some way in which the resistance of other building materials to lateral strains could be determined, it would be a long step in advance of the present condition of affairs.

The protection of structural iron in buildings from corrosion is another great problem, and it ought to receive more attention than has hitherto been accorded to it. Fortunately, the conditions are not so

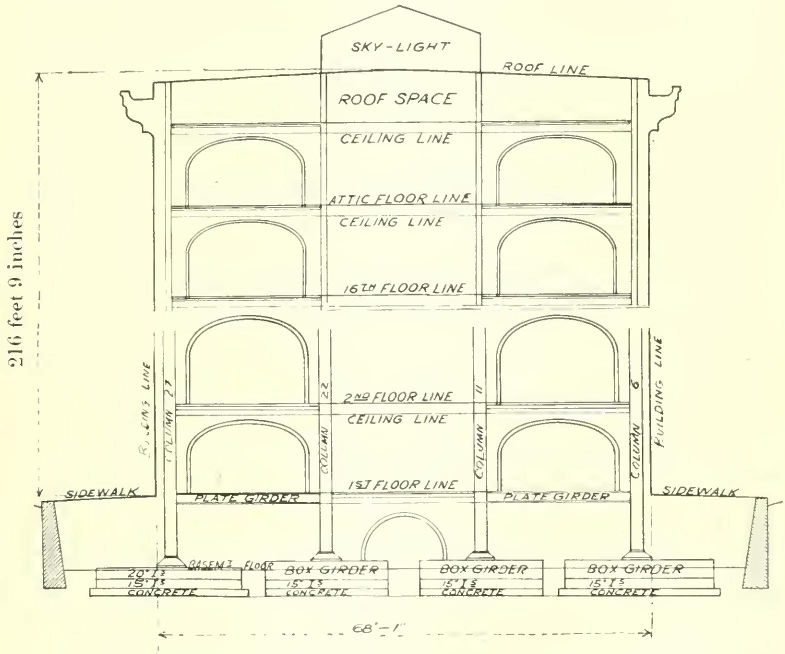

FIG. 9.—PORTAL BRACING, OLD COLONY BUILDING, CHICAGO.

difficult to overcome as those encountered in the effort to preserve iron ships, and structural iron in tunnels, in sea water, or even in ordinary bridges. Salt water is peculiarly destructive to iron in any form, causing corrosion in two ways, in the ordinary way where the material is exposed to both air and water and by galvanic action which it promotes wherever mill scale remains on the surface of the iron, or where different metals are used contiguously. Probably the most difficult problem of all pertaining to the preservation of iron and steel is the protection of the iron vessels used in salt water. The salt air along the coast is also very much worse in its corroding effects than the drier fresh air of the interior.

All iron work, however, whether near the coast or in the interior, which is exposed to the weather, must be cared for with a very great care indeed, or, it will, in a comparatively short time, become worthless. Acid fumes of all sorts promote corrosion, and this is especially true of the sulphurous smoke coming from the combustion of soft coal; and

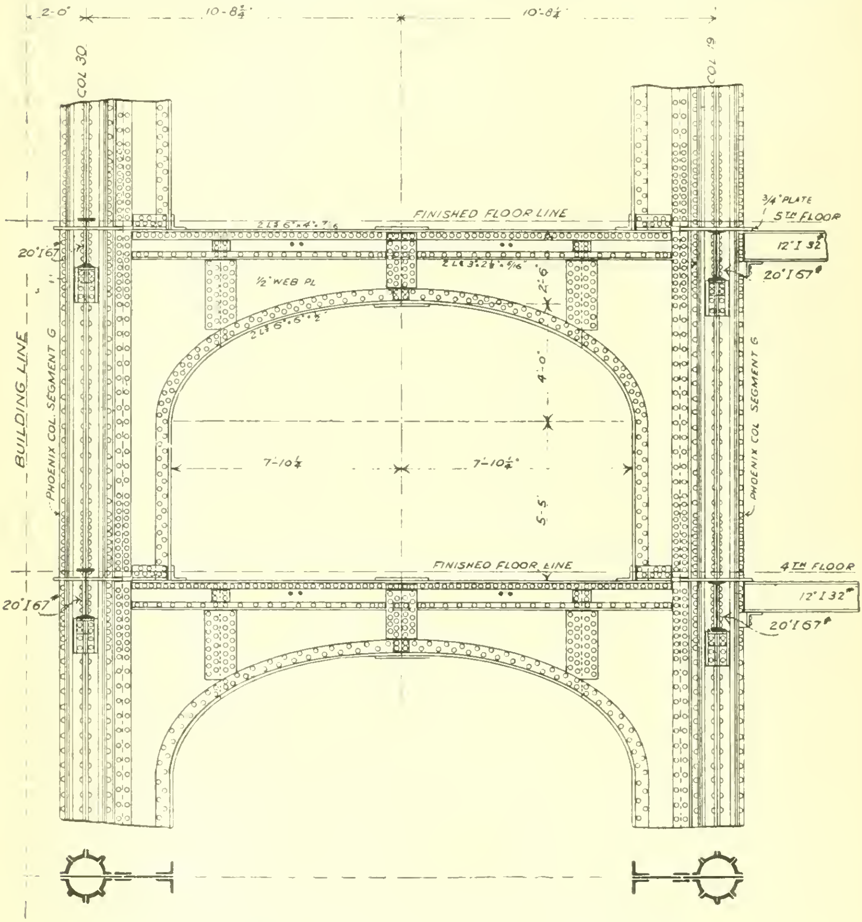

FIG. 10.—PORTAL BRACING, OLD COLONY BUILDING, CHICAGO.

also of the gases coming from factories or found in the ground under all the streets of our great cities.

None of these extreme conditions occur in buildings. In one way, the fireproofing of the iron in a building is a disadvantage. Under ordinary conditions, it prevents inspection, but it is really a great protection, because to a great extent it keeps out air and moisture. We

must understand and keep in mind the exact conditions of the phenomenon of rusting, if we are to clearly appreciate the character of this problem. Mr. M. P. Wood, an engineer in New York, in a recent paper on this subject, before the American Society of Mechanical Engineers, quotes from an article in the London *Engineer:*

"When rusting takes place under ordinary circumstances, the first stage appears to be the formation of ferrous carbonate. The carbonate is then dissolved in carbonic acid water to form ferrous bicarbonate, which latter is then decomposed in the presence of air and moisture, to

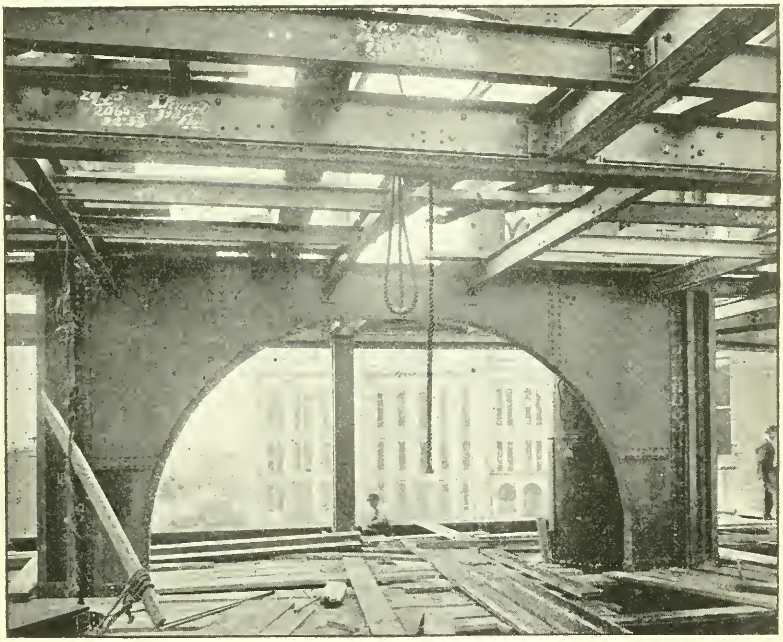

FIG. 11.—PORTAL BRACING, D. S. MORGAN BUILDING, BUFFALO, N. Y.

form hydrated ferric oxide, magnetic oxide being found as an intermediate product."

The paper states further "that neither bright iron nor steel will rust in pure water or in pure air. The presence of carbonic acid or some similar agent seems necessary, although the final product may be destitute of carbon. Even when oxygen, moisture and carbonic acid are all present, rusting will not take place unless the moisture condenses on the surface of the metal."

The force of this fact has a most practical illustration in the Baker Car Heater. This is a hot-water system, consisting of a heater, four to

five hundred feet of wrought-iron pipe and an air-chamber and drum usually fastened to the roof of the car. The water used for the circulation is saturated with salt, as much salt being used as the water will carry in solution. Some of these heaters were recently taken apart after

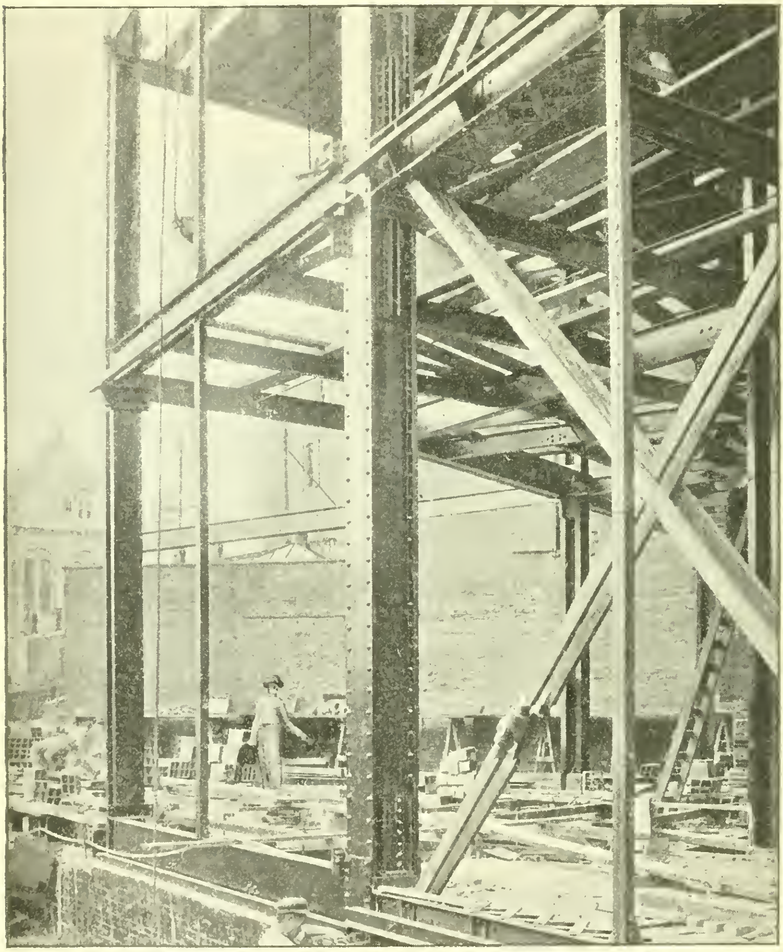

Fig. 12.—Steel Bracing with Diagonal Bars, D. S. Morgan Building, Buffalo, N. Y.

a service of nearly thirty years, and found to be entirely free from corrosion. The secret of this is in the complete exclusion of the air. If an iron column could be enclosed in a dry shell of fireproof material where the shell itself could not gather dampness, the column would last for-

ever, even if it were not painted; and, just to the extent that these conditions are realized, the fireproofing of the iron work in our large buildings is its best possible protection.

Danger of deterioration comes from the following sources:

Exposure,
Initial corrosion,
Initial dampness,
Permeability of fireproofing,
Imperfect fireproofing,
Leakage from pipes,
Noxious gases, and
Electrolysis.

In some buildings, structural metal is unnecessarily exposed, and exposure means corrosion unless the conditions are such that dampness can be excluded. The best interests of a building call for a complete and perfect covering of all the structural metal. This is done in a great variety of ways: Beams in floors are completely covered by the ordinary tile arches, using the word "tile" with its Western and better meaning. Interior columns are also covered with the hollow tile, while exterior columns are ordinarily covered with masonry. Several kinds of tile are used, both in floors and in partitions, and an indefinite variety of other materials and combinations of other materials, used and proposed for use in their stead. In the selection of these materials, their influence and effect upon the life of the steel work should not be overlooked.

Initial corrosion is another point very greatly neglected. Buildings are erected in both fair weather and foul, and care is rarely exercised to prevent any rusting before the iron work is enclosed. Yet who has not occasionally seen iron work in process of erection, which was completely encrusted with a layer of rust? A piece of clean iron or steel will, oftentimes, resist corrosion under very adverse circumstances, but when the rusting has once commenced, it is almost impossible to stop it. The ferric oxide is a great absorbent of both air and moisture. A spot of rust acts mechanically in bringing together the elements which are necessary to the chemical action. If the masonry covering absorbs moisture, the danger to the iron must be greatly increased by the presence, on its surface, of a body of rust. Even an initial condition of dampness ought to be avoided, because the iron might rust after it was covered, and then it would be as bad as if there had been initial corrosion. We occasionally see columns being covered in the wettest kind of weather, and it seems as if no one could afford the time to wait for the sunshine. There is a certain amount of initial dampness that cannot be avoided with our ordinary methods. So long as the coverings must

be constructed with wet mortar, we cannot have them perfectly dry at the start. But the danger from a damp wall often not touching the metal, as in the case of the fireproofing of columns, it is not near so great as that due to the actual presence of a considerable body of water clinging directly to the metal.

The first duty certainly is to take these simple precautions, concerning which there can be no question: cover all the metal, prevent corrosion before covering, and know that the metal is dry when it is covered. More than half the men who build great buildings do so with a view to large and immediate gains, and not to a conservative perpetual investment. The possibility of having a structural wreck in the next generation is not of so much importance as the saving of a very small margin of first cost, which these precautions would involve.

The permeability of different kinds of masonry, and of other walls used for enclosing structural iron, is very closely allied, in its relation to the durability of the metal, to the initial dampness due to wet mortar; and whatever destructive effects can grow out of the latter, can also grow out of the former when the permeability is great enough to permit a complete saturation.

The permeability of materials must not be confounded with their porosity. M. Paul Alexandre, a Frenchman, and Chief Engineer of Ponts et Chaussées, in discussing this subject at length, states that mortars mixed with fine sand are more porous than those mixed with coarse sand; but that mortars mixed with coarse sand are more permeable than those mixed with fine. Lime mortars are generally more porous than cement mortars. The permeability of lime mortars is not mentioned, but anyone who has lived under a leaky roof can testify to that. An increase in the proportion of cement in cement mortar decreases the permeability; age also decreases it; and all good Portland cement mortars become practically impermeable at the end of a few months.

Recently the fire insurance underwriters have outlined a scheme for a uniform and scientific rating of buildings, with reference to their fire risks. In a schedule which has been prepared for the purpose and which is largely used in Boston, New York and other cities, with a probability of a still more extended use, a premium is put upon what they consider safeguards against corrosion, consisting chiefly in the use of cast iron, instead of rolled material, and the use of lime mortar in contact instead of cement, while no penalty is provided for the omission of fireproof coverings around columns under certain conditions in certain buildings designated "fireproof." This fact is referred to in this connection, because it is very noteworthy that they should make this discrimination, and because the wisdom of the safeguards by which they

propose to preserve the iron work against corrosion, is questionable. If M. Alexandre's experiments and conclusions are correct, this schedule must be wrong in the statement that "cement must never be used in contact with iron or wood." Fr. Von Emperger, who has observed widely the practical working of Portland cement concrete and iron in combination, in the so-called "Monier system" for bridge and viaduct construction, and who is in this country now as a representative of the Austrian railways, states recently in a paper before the American Society of Civil Engineers that "concrete is the best conservator of iron," and more, that "it is a better protection than paint;" and supports his opinion by important illustrations in actual practice. If he is not right in his conclusion, pray tell us what will become of our far-famed Chicago foundations? Brick is, undoubtedly, a greater absorbent than mortars. The permeability of hollow tiles varies, but the possibility of passing moisture through them must be lessened by their hollow form.

The use of hollow tile around exterior columns between the masonry and the metal, as is done in the best western practice, is of unquestionable advantage in prolonging the life of the columns.

By imperfect fireproofing is meant partial, and badly arranged or badly constructed, fireproofing. Brick arches cover the webs of beams, but do not cover their lower flanges; holes through the fireproofing for the passage of pipes or for any cause whatsoever, make the work imperfect; and the omission of fireproofing in places to fix wooden grounds, or to otherwise connect interior finish, is exceedingly bad. The practice of placing centers of exterior columns so close to the building line that only a few inches of masonry, either brick or stone, can be put outside of them, is also very unwise. In some respects imperfect fireproofing is worse than no fireproofing. If the imperfection admits moisture and atmosphere where their work can go on unseen, a member may be ruined before anyone realizes that the process of destruction is going on.

Though the history of steel construction of buildings is limited, there are already some good illustrations of the quick and complete ruin that is certain to result wherever air and dampness can get into these hidden places. Recently, at the annual meeting of the American Institute of Architects, and later at a regular meeting of the American Society of Civil Engineers, Mr. Post, of New York, referred to the condition of some of the beams taken out of the old Times Building in New York City, after a service of about a quarter of a century. These beams carried brick arches on the lower flanges, the bottoms of the beams being uncovered. The corrosion evidently began at the bottom, but it crept upward between the iron and the masonry until the whole body of the beam was involved. The webs were entirely destroyed and

the flanges nearly so. The products of the oxidation looked more like hematite than iron. The room under these beams was used as a kitchen, and they were exposed to the steam and gases from a cooking-range. One of the peculiar girders shown in Fig. 1, which was taken from Sedgwick's Hall at Lenox, Mass., had been exposed near a door in the basement where the rain and snow could occasionally blow in and lodge upon it. When it was removed, not long ago, these exposed parts were found in this same complete state of oxidation ; what was originally strong iron could be broken away easily with the hand. Some very interesting pieces of both of these badly oxidized beams have been preserved by Mr. Robert Maynicke, of New York City.

Engineers cannot control all these conditions. The responsibility rests with equal, if not with greater, weight upon the architects. Their specifications for fireproofing should be very stringent on every point where practical precautions can be readily taken, as in this particular of complete and perfect fireproofing on every part. They should also secure the isolation of all pipes, keeping them outside of the fireproofing of the columns. Even if there is no leakage of steam or water, or of gases that are worse than either, from vent pipes, the fireproofing must be broken wherever connections are made, and that alone is sufficient reason for keeping them removed.

All noxious gases arising from the sanitation of the building or from any other source, should by no possibility be allowed to come in contact with the iron.

The effect of electrolysis on iron has come to public notice so recently that the exact conditions under which it can occur are but partially understood. We do know definitely, however, that magnetic currents promote oxidation. We also know that such currents are due to induction as well as to primary circuit. The insulation of electric wires in conduits is certainly a wise precaution even from this point of view.

The relative resistance of cast iron, wrought iron and steel to corrosion has been given an undue prominence in many discussions of this subject, for the other problems and conditions relating to their use, in a large measure control their selection. Steel is corroded more rapidly than wrought iron, and both steel and wrought iron are corroded more rapidly than cast iron. The use of steel and wrought iron in many pieces, with the strength of the whole dependent upon the rivets which hold them together, is, in this connection, another disadvantage, for the moisture that collects in the edges and the corners is held to do its mischievous work, while that upon the more exposed and continuous surfaces disappears. Avoiding the greater danger by the use of the least tractable metal, cast iron, is only begging the problem and half meeting the issue. Cast iron has its proper place and its proper use, but in very

high buildings we *must* have the lateral strength that comes from the use of hot rivets, and the stiffness and assurance of strength that come from the use of rolled material. Wrought iron, also, is out of the race, for it is practically out of the market, and its lack of strength, as compared with steel, is more than enough to make up the difference in their resistances to corrosion. And that difference is less than it is sometimes supposed to be. Cast iron is by no means everlasting. Mr. Wood, in his last paper on this subject, states that the greater resistance of cast iron to corrosion when exposed to sea water or to air charged with sea vapors "is probably due to the surface of the cast iron being covered with a skin of silicate of protoxide of iron produced by the molten metal fusing the sand in the mould, as well as to the film of magnetic oxide of iron formed at the same time by oxidation of the hot metal." If this is true, and it would seem to be a very rational conclusion, it would be especially true of heavy cast-iron columns. The collation of authentic testimony bearing on this question would be interesting, but ever so much of it will not solve the main problem, that is, the complete protection and preservation of all the structural metal. The underwriters are already discriminating against the general neglect to satisfactorily meet the whole problem; and they propose to discriminate more closely as the condition of the iron buildings already erected shows increased deterioration. Yet their interest in it is a bagatelle, as compared with that of the investor in such buildings, or with the responsibility of the architects and engineers. The deterioration of the metal can increase the fire risk in only two ways: a collapse of some part of the building might cause a fire, or it might increase the loss in a fire started in some other way. Some of our large buildings have a day population of several thousands; if there is any danger of a collapse involving a fire hazard, there is an equal danger of imperiling the lives of many people.

Again, even the possibility of a collapse on account of corrosion is extremely questionable; it is not probable, it is hardly possible; but the loss of the entire building is absolutely certain if the steel frame is not made good against corrosion. It will finally show its own rottenness, and will have to be taken down. The insurance man charges for the little risk he carries and seeks to define it as best he can; while the investor stakes his all, and gambles against a dead certain loss. It is hard to tell which is most to be criticised, the man who does the gambling, or the architects and engineers who help him to do it. It seems as if engineers and investors in all departments of construction were blind to the future. Mr. Wood, whom we have already quoted, says also,—"that corrosion will be so strongly developed in the Frith of Forth Bridge before fifty years have passed, that a drastic plan will have to be

adopted to prevent its destruction, and that because of the mistakes and neglect to properly care for it at the beginning, its life through the centuries will only be had through tribulation and sorrow." The miles of elevated railroad in New York are getting to be long streets of rust. We need somebody to blow a bugle blast so loud and so strong that legislators will hear, and that professional opinion will call with unanimity for special measures.

Without question, all iron work should have some preservative treatment in the shop, if not in the rolling mill. The mill scale is a dangerous element and ought to be removed from all iron work which it is seriously proposed to make everlasting. Rust should never be allowed to gather on such work. The best paint is a good preventive, but the ordinary painting of iron work in this day is wretched beyond all comparison. The paints themselves are bad, the oils are fishy, the paint is put on over scale and dirt and grease, in the rain as well as in the sunlight, over rust quite as willingly as on a bright surface, and without any particular care as to its completeness. A recent examination of two columns standing side by side in a New York building and painted by one of our leading manufacturers, is a good illustration of the general result. The paint on one had, as it were, dried up, and to a large extent disappeared, as if it had been a coat of powder. The paint on the other was sticky and blistered, and could be pulled off in long patches like pieces of thin leather, and possibly the two columns were painted at the same time and out of the same pot.

The ideal paint must have no ingredients that can deteriorate iron or steel, or in any way promote their corrosion. Such a paint must cling tightly to the metal; it must dry quickly; it must set with a surface hard and smooth, but tough enough to resist injury in handling or otherwise; and it must be unaffected by atmosphere, water, or gas, or by heat or cold. The ordinary paints in the markets, with their multifarious adulterations, are of little value to meet these specifications. Pure red oxide of lead, mixed with pure linseed oil and applied immediately, has, up to date, given the best results, with the possible exception of the graphite paint manufactured in Detroit, the true value of which is not yet determined. The red lead, however, must be applied immediately after mixing, or it will not cling to the metal. Iron oxide paint promotes rather than prevents oxidation, and should not be used on structural iron. Zinc-white blisters; lamp-black is not hard. Mr. Wood's treatment of the subject of paints in his recent article is quite complete, and his references to other literature on the subject are exceedingly valuable. The graphite paint referred to is a comparatively new product, manufactured from native ore obtained in the Lake Superior region. It becomes hard very quickly after being applied; a

characteristic which, the makers claim, is due to the proportions of alumina and silica contained in the ore. It clings tightly to the metal, does not blister, sets hard, and seems to be exceedingly tough. The manufacturers have an ordinary grain bag saturated with this paint, which has hung, full of water, in their factory for three years. During this time the water has twice been frozen solid, and the bag itself is apparently as pliable to-day as before the paint was applied. Canvas saturated with the paint is also fireproof to ordinary exposure. Altogether, it is very worthy of the careful investigation of engineers and architects. All paints should be applied upon clean metal. Painters sometimes prefer to apply paint over rusted surfaces, because they say it sticks better. The chances are, however, that paint applied in that way will not be weatherproof, that the oxide already found will absorb both air and moisture, and that the corrosion will go on underneath the paint unobserved. It is claimed for the graphite paint that its chemical characteristics are so antagonistic to moisture in every form that the paint will counteract such injurious tendencies; yet the fact remains that all paints should be applied to clean surfaces, which should also be dry, and, if possible, warm. Wet surfaces prevent the paint from clinging to the metal and cause blistering. Where iron work is exposed to underground dampness, as it always is in foundation work, waterproofing courses of asphalt are of unquestionable advantage; and hot asphalt applied to iron work so exposed can be used instead of paint, but the value of such applications will depend largely upon the quality of the material and the thoroughness with which it is applied.

Much has already been said about fireproofing as a protection against corrosion, but our treatment of the general subject would hardly be complete without some reference to fireproofing as a fire protection. It is very necessary that the large buildings, which the use of steel has made possible, should be absolutely fireproof. This is true, not only because the number of people who occupy them and the value of the property in them are very great, but because their greater height increases the difficulty of exit and makes it extremely difficult for firemen to operate. Such buildings ought to be made absolutely and completely fireproof against any fire within or without. A great many criticisms have been written about fireproof buildings that burn, so much so that there is a popular notion that no really fireproof buildings can be built. Such statements were common after both the great fires in Boston, but the president of one of the leading insurance companies states that not a single building destroyed by these fires was rated as fireproof; and it is quite notable that the only building left standing in the business center of Chicago after its great fire, survived because it was indeed fireproof.

Our opportunities to judge accurately by observation concerning

the values of the various methods which are used to make the fireproofing complete and perfect, are exceedingly limited. Generally, when fires occur in fireproof buildings, they are so insignificant that no record is made of them; and when fires occur in buildings that are not fireproof, the destruction is so complete that it is difficult to estimate the value of whatever good fireproofing may have been in the building. During the last few years, there have been several fires in the Rookery in Chicago, and one of them, at least, would have consumed the building, if it had not been a fireproof structure. In the interior of the building are a number of janitors' closets, one right over the other. As they could not be ventilated through windows, iron gratings were put in the floors, and the whole system was ventilated, every room through those above it. Every night the refuse of the building is gathered temporarily in these rooms. The fire started on one of the lower floors as soon as the material was gathered for the day. In a moment the entire stack of rooms was a blazing furnace, and the heat must have been intense. Everything in them that could burn was consumed. The work of the firemen had, probably, little to do with stopping the fire. The damage was very small. It showed a weak point in the construction of these rooms, but also proved that the building was well constructed to resist fire.

Probably the most remarkable illustration of the fact that buildings can really be built fireproof is afforded by the fire in the Chicago Athletic Building. This building, constructed by the Chicago Athletic Association, is about 84 feet wide, by 170 feet long, and eleven stories high. The fire occurred shortly after its completion, and the damage was confined to the portion above the third floor. The fifth floor is all one room, a great gymnasium, with a running track extending entirely around it about ten feet above the floor. Heavy steel box girders about 40 feet long, and a few zee bar columns, supported the high ceiling of this room and all the floors above. The upper floors are used for bedrooms, dining-rooms, and courts for indoor tennis and other games. The interior finish is solid oak, all the halls being wainscoted with it, and all the walls and the ceiling of the gymnasium being covered with it. Indeed, it even covered the columns. At the time the fire occurred, this finishing material was all in place, and the painters were just finishing the dark antique finish in the gymnasium. The false work, made of 2-inch plank, erected for the workmen engaged in the erection of the heavy paneled ceiling, extended, with its supports, over the entire area of the room. Carpenters' benches and chests occupied every vacant place; some thousands of feet of lumber were piled in the room, awaiting use in other parts of the building, and the heavy oak floor was covered with shavings, blocks and other refuse. The fire, which was undoubtedly of incendiary origin, consumed everything combustible

that was in this room, and so thoroughly that it was difficult to find even charred pieces. The intense heat can be better imagined than described, most of the wood-work in other rooms was consumed, even the floor being burned away in many places. The total loss was reported to be about $60,000. The damaged steel work, however, was replaced for a very small amount, not more than a few hundred dollars. The only beams that were exposed were between the elevators, and the expansion of the iron guides buckled them all. The chief loss occurred in the destruction of the delicate stone tracery in the front of the building; and this was due more to the water thrown upon it, than to the fire. The strength of the building, both in its masonry and in its steel construction, was not in the least impaired; the tile arches in the floors were not injured to the extent of having to be renewed.

The most important lesson which the fire taught, pertains to the fireproofing of columns. In this case, the long columns in the gymnasium were not properly cared for. Before any fireproofing was put around them, they were encircled, at about every four feet in height, by wooden frames made of 2x4-inch scantlings spiked together. These were for grounds, and to provide a backing to which the oak wainscoting could be nailed. Betweed these strips, the columns were enclosed in hollow tile blocks in the ordinary way. The fire burned these frames, and the covering of the columns dropped to the floor. The columns, fortunately, were not injured, but that fact is not to the credit of good fireproofing. If the columns had given way, the destruction of the building would have been complete, but the real fault would never have been known, and meritable measures would have been condemned.

The fireproofing around columns should be continuous from floor to floor; it should be well constructed, and the pieces should be anchored together entirely around each column, preferably with copper wire, every four or five feet in height. The space between the fireproofing and the iron should be left vacant. Columns in the exterior walls should be covered with the hollow tile just as thoroughly as those in the interior; and should have, at least, five inches of brick work or other masonry well laid in cement mortar between this and the outer air. The hollow spaces are just as important around the exterior as around the interior columns; and the five inches outside of the fireproofing will gave space for the width of one brick and a well-laid coat of Portland cement between it and the fireproofing. Lime mortar should not be used for this work. If the character of the brick requires it, or if, for any other reason, lime mortar is necessary, a coating of some waterproof material should be used outside of the fireproofing.

Four inches of brick work alone, between the steel work and the outer air, is not good for protection against either fire or corrosion, while

four or five inches of limestone is almost no protection at all, and should never be permitted. Marble and limestone are not fireproofing materials. The New York Building Law provides for the use of bond stone in heavy brick masonry. The use of limestone in this way endangers the whole structure. Where limestone and marble are used to finish the front of a building, it should be done in such a way that the strength of the structure does not materially depend upon it, and so that the masonry can be replaced in case of injury. The risk that is run in using limestone for an exterior finish and in relying upon it for the strength of the building, was never better shown than in the Athletic Building. The loss of the stone work in this fire was very great, but the steel work, over the part of the wall which was destroyed, preserved the front in the upper stories, so that it was not materially injured.

The whole subject is too great for a proper consideration here, but it may be emphasized that buildings can be made completely fireproof, by covering all the iron work with the hollow material made for the purpose, and fastening it in position so that it cannot be readily tumbled down or stripped off. The air spaces will prevent the heating of the metal to a danger point, either by yielding or by expanding. Almost any material made in hollow block form will serve the purpose, if it can be protected; but if it is exposed, so that water can be thrown on it while heated, it should be of porous material, for the very hard clay tiles are apt to crack to pieces under such treatment.

Non-inflammable materials for interior finish are desirable. Stocks of goods that can readily burn, or quantities of inflammable materials, should not be allowed in buildings above the convenient reach of firemen, say seven or eight stories—but the steel can be protected so that the building will not burn even if they do. The use of metal in buildings is demanded, and this and all the other problems that belong to it can be, and must be, satisfactorily solved.

NOTES ON A BROKEN PINION SHAFT.

By Onward Bates, Member of the Western Society of Engineers.

[Read October 3, 1894.*]

On July 8, 1893, a breakage occurred to a pinion shaft operating the C. M. & St. P. Ry. drawbridge over the Menominee River at Milwaukee, showing so peculiar a fracture that photographs were taken of it, two of which are submitted for the inspection of members of the Society, with the following notes compiled from a report of the accident by Peter Sullivan, the Railway Company's Iron Bridge Inspector.

The bridge is a double-track iron structure, 203 feet long, built in 1886 and opened to traffic December 19th, of that year. The failure was the first of its kind, and did not cause any interruption to either railway or river traffic, as the bridge is provided with separate hand-turning gear. A new shaft was provided and put in service the day after the accident, and it was again operated by steam power. The bridge is easily turned by two men with the hand gear, and when steam power is applied, a boiler pressure of 30 pounds is usually carried. Complete reports of river traffic through the draw openings are not at hand, but there are records of the bridge being opened 10,417 times in 1893, and 11,997 times in 1892. It is estimated that it was opened 12,000 times per year previous to 1892.

The broken shaft is one of two pinion shafts, each $3\frac{7}{16}$ inches in diameter by 4 feet $3\frac{3}{8}$ inches long, working in sleeve brackets 3 feet, $1\frac{1}{2}$ inches long, with bearings $8\frac{1}{2}$ inches long at each end. The upper end of each shaft is fitted with a spur wheel 26 inches diameter and 5 inches face, driven by an intermediate shaft which, in turn, is driven by an equalizing shaft acting through bevel gearing. The intermediate shafts have their bevel wheels set in opposite ways, one with the bevel up and the other with the bevel down, in order that they shall turn in the same direction while being driven from the opposite ends of the equalizing shaft. To provide for disengaging the other gearing from the pinion shafts when the bridge is operated by hand, one of the bevel wheels is made to slide on a feather, and the other has a clutch coupling. After the accident, the feather was found to fit snugly in its seat in the hub of the bevel wheel, and the clutch coupling to have nearly an inch of play, or lost motion, where it engaged with its bevel wheel. The significance of these fits will appear hereafter in accounting for the

* Manuscript received March 11, 1895.—*Secretary, Ass'n Eng. Socs.*

broken shaft. The lower ends of the pinion shafts are fitted with spur pinions, $11\frac{1}{2}$ inches in diameter and 6 inches face, engaging with the rack circle on the pier. The pinion shafts are geared to the engine in the ratio of 1 to 25, and revolve about seven times in opening or closing the bridge, which ordinarily occupies about forty seconds.

When the shaft failed and was removed, it was found that the break had occurred inside of the sleeve bracket, about six inches from the lower end, with the fracture extending upwards nearly twelve inches. Between these points the shaft was completely broken in two places about five inches apart, with the short section split in four pieces. The photographs, which are a little over one-sixth size, show the broken shaft plainly. It is to be noticed that the appearance of the fracture is as if the shaft were a wooden one covered with black oil. Indeed, the small pieces of the shaft were taken to be of wood by some who saw them.

The shaft which was broken is the one operated by the loose-fitting clutch coupling. Mr. Sullivan's theory of the break, with which the writer agrees, is that it was due to the shocks caused by the one-inch lost motion in the coupling in starting and stopping the bridge. Counting four shocks (starting twice and stopping twice) to each time the bridge was opened, there were approximately 315,000 shocks applied to the shaft, and alternating in torsional direction. The shaft was of badly welded iron, and, in being twisted back and forth with jerks, the seams gradually opened and the oil used in lubricating the shaft penetrated between the parts, lessening the friction between them, and this process continued with the pieces held together in the sleeve until they were completely broken, as shown in the photographs.

This theory of the fracture is supported by the example of the other shaft, to which the power is applied by the bevel wheel sliding on a

feather without any lost motion, and which is in apparently good condition, although doing the same work as the broken one.

The clutch was evidently made with too much play at first and this perhaps was increased by wear. The mass of the moving structure was so great that with a force suddenly applied to the shaft, the resistance was similar to that of an immovable body and the shock was to be measured by the power of the engine. Such shafts under unfavorable conditions are subjected to heavy stresses, and for example it may be mentioned that on two different occasions steel shafts 5 inches in diameter were twisted in two in the Kinzie Street railroad bridge, in Chicago, before it was rebuilt.

The writer makes no apology for choosing as his subject a small detail when he might have presented a whole bridge to the Society, for he wishes to draw the moral that correct designing means attention to

details, and that we cannot know all about details until we have learned their wearing qualities.

Mr. Goldmark.—Was the shaft made by rolling or by hammering?

Mr. Finley.—By rolling.

Mr. Goldmark.—This is a case where wrought iron failed because it was wrought iron, because it consisted of a number of layers the seams of which were not properly welded. The author speaks of this as a badly designed detail, but it is a question whether the design or the material is bad. In other words, would it not have opened just as much in a 5 inch shaft as in a $3\frac{1}{2}$ inch shaft? Those who have had something to do with rolled iron shafting have often come across this opening in

welds. Wought iron, which by many is still considered far more reliable than steel, has, in this case, as in many others, shown unexpected weakness.

Mr. Artingstall.—Why is it that we recite in our specifications that the size of ingot and the size of hammer shall be under the direction of the engineer, excepting that it is to see that the metal is properly worked? I judge that in this case the metal has not been properly worked.

A METHOD OF MAKING RIVER SURVEYS BY STADIA EXCLUSIVELY.

By J. L. Van Ornum, Assoc. M. Am. Soc. C. E.

[Read before the Engineers' Club of St. Louis, January 16, 1895.]

For a complete survey of a river, where latitudes and longitudes, as well as the most exact location of all the salient features of the river and its surrounding territory, are desired, no method can supplant a complete triangulation system. Also, in the case of a river of great size, whose territory is extensive and whose width is great, a system of triangles throughout its extent and the location of soundings by angular measurements are essential. Minor modifications are often made, and details changed to suit varying conditions under which the work is carried on; but whenever a river, from its size or importance, requires the most exact survey possible, recourse is necessarily had to the extensive, though expensive, system of triangulation, with the accompanying intersection system of locating soundings.

Mr. Walter G. Kirkpatrick (in a paper read before the Engineering Association of the South), has suggested a modification of the well-known triangulation methods, in which their exactitude is relaxed in the interest of economy and speed. This method involves triangulation also, but of a much more temporary and approximate character.

Its principles, as set forth, involve a network of triangles covering the river, the stations on one bank being opposite those on the other, and on the ground near the water's edge. Stations are spaced at a distance about equal to the width of the river. A base line, from one station to the next adjacent one, is measured every thirty or forty stations, in order to check the work. In measuring the angles, the transit occupies stations on only one side of the river, the supplementary angles on the opposite bank being computed. In this way the triangulation is effected, and from its data the computation of necessary distances is easily and quickly made and the plotting simplified by the use of the system of chords, the checks being numerous.

The author does not state his recommendation for completing the meandering more in detail, nor for the location of soundings. Presumably any of the usual methods might be used. This modified triangulation method would seem to be applicable where the usual littoral growth of standing and overhanging trees, brush and often cane, become so light as not to interefere seriously with the necessary lines of sight along the occupied bank.

For any ordinary river survey, the stadia method furnishes the best system, both because of its economy and on account of its efficiency. It is, of course, not so accurate as triangulation, yet its accuracy is amply sufficient for a survey for navigation or for improvements, or for any purpose up to the most rigorous if it is within the scope of the method. This scope limits it to rivers not much more than one-half mile in width, because the location of the soundings, as well as the meandering of the banks, is made by the stadia, and the sights must be kept within practicable limits of length. The following is the general plan of operations, in the light of which its efficiency and economy will be made more clear.

The purpose of a river survey is, in general, to determine its course throughout, its depths in detail, its slope, the position and character of its banks, the nature of its bed, its ruling velocities and its discharge at different stages. Should the purpose not require all these investigations in detail, the survey will be to that degree simplified.

In the stadia survey, five parties are required, viz., two transit parties, two level parties and one hydrographic party.

The two transit parties are similar in their work and in their personnel. The latter, in each party, consists of a transitman, two stadia-men and a boatman with a boat. All measurements are taken by stadia and directions by successive azimuths (or angular deviation from the meridian). Of the parties, one works, if possible, on each bank of the river, back from the usual littoral growth of trees, and so is generally unimpeded by them. Its duties are the accurate meandering of its own bank, the taking of the topography of the adjacent country back to the highest flood line where practicable, the noting of the character of the river banks, and the location of necessary points established by the hydrographic and level parties and described later. The meandering of the banks requires the surveyed line on each to follow the river's direction. It involves, besides the necessary located points, observations on polaris for azimuth at least every twenty miles of progress. Reciprocal sights for azimuth and distance should be exchanged between transitmen every two or three miles. Such sights furnish data from which the latitudes and departures of such circuits are computed, thus checking the work in the field. If an error of any magnitude, either in azimuth or in latitudes and departures, is discovered, the field work of the circuit is retraced, and the error found and corrected. The average error of closure should not exceed $\frac{1}{700}$, and that of azimuth should not exceed 2′ per mile; and the extreme limits allowed should not exceed double these amounts. The topographical points, and points located for the hydrographic and level parties, will be made by secondary (side) sights from the occupied stations of the closed lines.

A level party works on each bank, each carrying forward its level line. Each party contains a levelman, one rodman and one boatman with boat. Each party should, on its own bank, keep as nearly as possible abreast of the hydrographic party and take the elevation of water surfaces (located by the transit parties) at the time and place of sounding, as frequently as is necessary, *i. e.*, very frequently at bars or shoals and much less frequently at pools. Permanent bench-marks should be established at each shoal, and also between shoals, if the distance is greater than four or five miles. Reciprocal sights for elevation should be exchanged between the two levelmen every two or three miles, and, if a discrepancy of any size is discovered, the circuit should be re-leveled.

The hydrographic party is charged primarily with making the soundings, which are located by angle and stadia. It consists of a transitman (with his individual boatman and boat) and a large sounding-skiff containing a recorder, steersman, leadsman, stadia-man and two or three oarsmen.

The sounding boat will define lines from bank to bank, and also lines in the direction of the river's length, thus covering the river with a "gridiron" of sounding lines. These cross-lines and longitudinal lines will be at a distance apart depending on the purpose of the survey and upon the ascertained depth of water, the spacing being much closer in shoal water. Straight lines will be secured by the steersman, who will choose natural ranges on the bank ahead, or by other similar methods familiar to river men. The method of location herein recommended permits of constant oversight by the transitman, thus assuring at the time straight lines correctly spaced.

The general oversight of the party rests with the transitman, while the sounding boat is under the immediate charge of the recorder. The leadsman is in the bow of the boat and the stadia-man close to him, with his stadia-rod always vertical and facing the transitman. When working, the steersman keeps the boat on the desired line, and the leadsman takes the soundings (with lead-line or sounding-pole) as frequently as desired, calling to the recorder the depths and character of the river-bed. At the same time the transitman is taking his observations of stadia-reading and angle as frequently as possible, each location being timed to coincide with the vertical lead-line and the vertical hair being directed to the lead-line for the angular reading; the stadia-rod being so close to the leadsman makes it practicable to read the stadia interval, although it is not in the center of the field. The transitman records his observed stadia interval and then reads and records the corresponding angle, thus fixing the position of the sounding by polar co-ordinates.

The practicability of making accurate readings on a stadia-rod held in a boat depends mainly on care on the part of the transitman. In the boat, the stadia-rod should be well braced, at the bottom, in a temporary way, in each position, and the stadia-man should have a high and firm seat to enable him to hold his rod steadily in its vertical position. The transitman, having, for convenience, his transit generally near the water's edge, habitually keeps the lower hair at a reading about equal to his height of instrument above the water, thus requiring little movement of the gradienter to accurately place the lower hair for successive readings. When preparing for a sight, he turns the alidade with his left hand to bring the vertical cross-hair to coincide with the lead-line as it becomes vertical, while, at the same time, with his right hand he moves the gradienter whatever small amount is necessary to produce a coincidence. This preparation enables the transitman, when the vertical hair does coincide with the vertical lead-line, to note at the same instant the reading of the upper hair, and so read the interval. In this, as in other work, repeated observations soon lead to expertness. If the water is somewhat rough, the lower hair would usually stand at the mean height of the mark; then, at the critical instant, a quick movement of the gradienter will obtain a correct setting, which is read as before. The size and load of this boat also lessens the disturbing effect of the waves. Quite a sea is necessary to vitiate the readings, and when the water is rough enough to make them unreliable it is rough enough to vitiate the readings of the lead-line, and work should, of course, be stopped.

We must now consider the means of identifying corresponding observations in the books of the transitman and recorder,—that is, ascertaining which sounding recorded corresponds to each location. Time locations would furnish an accurate means, but, were this plan used, there would be lost one of the advantages of this method of location, viz., its elasticity, which allows the transitman to make as frequent locations as his manipulations will permit. To effect this object, the best plan is for the transitman to have his boatman or assistant wave a flag at the instant he makes a location; this is seen by the stadia-man in the boat and repeated to the recorder there, and both transitman and recorder make corresponding entries. To obviate error due to loss of a signal or to mistake, differently colored flags are irregularly used, and each field book shows a corresponding record of color opposite the proper entry. Thus both the transit book and the sounding book have a corresponding succession of color signals for each line, each location in the transit book applying to the sounding denoted by the correctly corresponding indicated color. Of course, the beginning and end of each line furnish distinctive points of identification and reference by

time observation, noted by both transitman and recorder, and, at the close of each day's work, the corresponding observations on each line, as identified by the color of flag, are numbered.

The particular advantages of the stadia method are economy, a greater frequency of location and a more thorough covering of the area, due to the fact that the position of the lines of soundings is instrumentally observed in such a way that they are subject to the perfect supervision and immediate correction of the transitman. This insures a complete covering of the area, without the necessity of an accompanying office force to plot the soundings in the field.

The positions of the transit are arbitrarily chosen to the best advantage as determined by the meanderings of the river, and are from one-fourth mile to one mile apart. Whenever the sounding lines have progressed a sufficient distance beyond the transit station, the latter is marked by a flag and abandoned by the transitman. He is then taken by his boatman to the next advantageous location for his station, while the sounding boat waits in position; then observations are continued from this place as before. Preparatory to measuring the location angles of soundings, the zero of the horizontal limb of the transit is always set either on one of the stations previously occupied by the transit, or on a station established for the purpose, and marked, as are the others, by a flag. The stations just mentioned are located from at least two stations occupied by one of the transit (bank) parties, thus connecting the meander and hydrographic surveys into one complete and connected whole. This fact makes it necessary for the hydrographic party to be always in advance, with the level parties as nearly abreast as possible and the transit parties closely following.

It will be found that the transit parties are often more than able to keep up with the hydrographic party. Their spare time can be advantageously employed in taking borings in the river bottom where necessary, and in velocity measurements and observations for cross-section and discharge, under the direction of the chief of party.

Gage readings to determine the stage of water at the time of survey, methods of reduction of soundings to equivalent depths at low-water stage, computation of low-water profile from that at the time of survey, discharge computations and other reductions and operations are made in the usual way, and do not properly come within the scope of this paper.

The system described is elastic, allowing modification to suit particular cases. Thus, if the stream should be a small one, permitting both banks to be within the reach of one transit and one level, a single transit party and a single level party would suffice where economy is necessary. In this case the level line would be checked approximately by transit

levels, and the transit distances by the hydrographic work. Or, if the greatest economy is desired, with a limit of accuracy such as is obtainable in compass work, a single instrument man with a transit will make the whole survey. In this extreme case, the meandering of the river would be by stadia sights and compass bearings, the stations being at the water's edge. Secondary sights would locate salient points of the banks, from all of which the bank line would be drawn. Level readings on the rods would give water surfaces for the profile and the reference plane of soundings, and, from the located points on the banks, the channel depths, as obtained, would be sketched in where of ample depth. Where the depth is questionable detailed surveys are made in the usual way, by polar co-ordinates, as is also the case where cross-sections for discharge are desired.

The rate of progress varies from six or seven miles per day, for the case last mentioned, to a mile or a mile and one-half per day for the most complete survey. The cost of field work would correspondingly vary from four or five to sixty or seventy dollars per mile.

The writer has used the system, as described in this paper, with its various modifications, on several river surveys aggregating over 400 miles. Hence the system has not only borne the test of experience, it is a growth developed by conditions and exigencies that have arisen in experience.

To restate the argument briefly, the particular advantages of this system of stadia hydrographic surveys are:

(1) Economy.

(2) Elasticity of adaptation to conditions.

(3) More numerous locations of soundings.

(4) A more accurate location of soundings than is often practicable by two transits on the bank taking simultaneous pointings, and a much more accurate location than is possible by the three-point problem, using a sextant in the boat.

(5) Adequate and complete instrumental oversight of the work at the time.

ROAD IMPROVEMENTS IN KNOX COUNTY, TENNESSEE, AND FULTON COUNTY, GEORGIA.

By J. E. M. Hanckel, Member of the Association of Engineers of Virginia.

[Read January 26, 1895.]

I have selected for discussion the road improvement system of Knox County, Tenn., and Fulton County, Ga., because they represent the same geological formations that confront us in our two sections of Virginia, known as Southwest Virginia, and Eastern or Piedmont Virginia.

Knox County, Tenn., abounds in limestone cliffs and ledges, that break out on the surface in all parts of the country. In building roads here, it is possible to open, at almost every mile, quarries which will furnish excellent macadam. On many miles of roads, the material from the cuts which are made in order to reduce the grades to the maximum (which is 5 per cent. except in emergency places), is a hard, blue limestone, and this is broken to proper sizes, put on the road-bed, and thoroughly rolled.

It is not necessary to present to you a description of the modes of construction used in this county. That they are good, is all that is necessary to say of them. The construction of new, and the improvement of old, roads is in charge of the Board of Pike Commissioners, the County Judge being Chairman of this Board. These Commissioners are permitted by law to employ, on their roads, all convicts committed by their County Courts; and the cost of supporting these convicts is met from the general funds of the county. With this force they build on an average eight miles of macadamized roads each year.

There is also levied a special road tax of 10 cents on $100 worth of property in the county, including the taxable property in the incorporated cities. The funds derived from this tax also are placed in the hands of the Pike Commissioners; and with this they build about seven miles of macadamized road each year. This one county thus builds fifteen miles of macadamized road each year.

Leading out of Knoxville there are ten roads which are graded to a 4 per cent. grade, and so well macadamized that one can drive for ten or twelve miles in any direction on them in the worst winter weather at a brisk trot, and be able to plead not guilty to the charge of being a mud thrower. These roads have been made what they are, however under the most advantageous surroundings.

Turn now to the roads of Fulton County, Ga. The Commissioners who have shown themselves so efficient in Knox County, Tenn., would make many blunders here. The soil of this county is red clay, with quite a large percentage of mica. When this becomes wet under constant rains, the roads are almost impassable. Here there is some stone that can be quarried and crushed for macadamizing; but there is very little of it, and it grinds down rapidly under traffic and frost, and is then washed away by rains. These macadamized roads, therefore, soon become rough, and are very expensive to maintain in proper repair.

The roads are built and repaired under the direction of the County Commissioners, who appropriate each year a certain amount for roads. The general levy of the county is made on property in the city limits of Atlanta, as well as on all other property of the county. The Commissioners lease from the State about two hundred convicts, who are kept at work on the roads all the time.

These Commissioners have abandoned macadamizing altogether. They pave about fifteen feet of the roadway, altogether on one side, with cobble or common rubble, which they quarry and break into proper sizes instead of crushing to egg size. They pave from six to twelve miles of road per year with this force, and have already improved in this manner many miles of county roads.

I have shown that the two cities of Knoxville, Tenn., and Atlanta, Ga., besides maintaining their own highways, contribute (and, of course, by far the largest part) to the expense of building and maintaining the county roads. This is just, as all roads naturally lead to the important town or city of the county; and this town or city is better able to pay for such improvement, and will reap greater benefit from it, than any other part of the county.

I believe that we should have in Virginia such a road law as these counties have. We cannot expect the small values of county property to stand such taxation as would, of itself, provide sufficient funds for such road improvements as we must now inaugurate if we are to keep pace with our sister states. We have a State that is capable of just as much progress as these have made.

I trust that our Association will be the instrument of inaugurating in Virginia a good road system, the working of which will redeem our State from the disgrace now facing every county official.

COUNTRY ROAD BRIDGES.

By C. C. Wentworth, Member of the Association of Engineers of Virginia.

[Read October 17, 1894.*]

Part of the making of a good road lies in making the bridges good. A good bridge is one that at a reasonable first cost is strong and durable, accommodates the traffic, and requires the least yearly expenditure for its maintenance. The good appearance of the finished bridge is also to be considered; but for ordinary county road bridges that good effect in looks which always follows the execution of a well-planned engineering work may be relied on to fulfill this desideratum. A neatly designed portal is generally used to ornament the structure. It should be entirely devoid of the very slender open ironwork that is often found on portals and which is always disfiguring.

It may be stated that since iron structures can be built at almost as low a first cost as wooden ones, there should be as little wood used in the bridge as possible. Even the joists that carry the flooring should be of iron or steel; timber appears at present to be the material best adapted for the flooring itself. If metal joists are used, which are simply rolled beams, the cost of the bridge will probably not be increased beyond the amount expended in the first renewal of the timber joists. It is an easy matter to take up and renew a floor plank that shows signs of decay, but to renew or even examine the timber joists is a difficult undertaking.

The supports for the ends of the bridge should be of stone whenever stone can be procured. The plan of using iron cylinder piers is to be avoided if possible. Masonry ought to be made of reasonably well-shaped stone laid up in real cement mortar. The cement must set hard in a week or less. If the stones used are hard and durable, their shape is of little importance, provided they are all held together in a solid mass by good cement. In order to make good cement mortar it is absolutely necessary to have not only good cement, but also clean, sharp sand. By looking after these points, we can build at a low cost, a wall that will stand indefinitely, as far as the masonry is concerned. If no good stone can be procured, then iron cylinders of from 2½ to 5 feet in diameter are used. These are made of iron plates not less than one-fourth of an inch in thickness, bent into a cylinder and riveted. Each pair is also braced together across the bridge. These cylinders are

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filled with concrete. A good plan is to bolt them to a platform of timber placed low enough to ensure its being always wet, so that they can not settle or be pushed over.

For short spans, up to say 30 feet, rolled beams can be used, with the floor plank laid directly on them. For longer spans there is no better form of bridge than that known as the Pratt truss. These are generally through bridges, or what are called half-through or pony trusses, the latter being used for spans up to about 80 feet. For very long spans, a modified form of Pratt truss is sometimes used, which has the ends of its top chord somewhat inclined, instead of being level. These are known as elliptic, or Baltimore trusses.

In pony-truss bridges the sides are from 6 to 10 feet in height, so that there is no room for overhead bracing to keep the top chords in position. This is the weak feature of a pony truss, and is to be guarded against by making the vertical posts with a rigid connection to every floor beam, so that by their stiffness they hold the top chord in place, the top of each post being connected to the top chord. There ought to be a post at each end of every cross floor beam, and the inclined end post should extend straight from the end of the span to the top of the first vertical post. There is used sometimes a kind of truss in which the end post meets the top chord at a point several feet from the top of the first vertical. This form should be entirely discarded, for the reason that every panel point of the top chord should have a vertical post to support it and keep it in line. It makes no difference how much the end post is inclined, provided the height of the side truss is kept one-sixth to one-tenth of the span. It is a good plan to make the vertical posts of a pony truss about 2 feet wide at their lower ends where they connect to the cross girder, and taper them up to the top, where they are made small enough to enter the top chord. The 2 feet of width of the base makes it convenient to connect them rigidly to the cross floor beam.

Through Pratt truss bridges are used for spans longer than 80 feet. These have inclined end posts, but, as the trusses are high enough to admit of cross bracing overhead, there is no need of the same dependence on the vertical posts to keep the top chords in place, so that the first vertical is made a tension member. The head room over the floor to the under side of the portal bracing should be not less than 14 feet.

The floor joists of all county road bridges ought to be proportioned to carry a live or rolling load of 100 pounds to the square foot of floor surface. This will provide for any heavy single load that may be met with on such roads, so that it can go anywhere on the bridge with safety. As it is not at all likely that a great number of such heavy loads will happen to be on the bridge at one time, so as to cover all the floor at once, the cross floor beams that come at every panel point may be pro-

portioned for a lighter load, 80 pounds per square foot of floor surface being sufficient for them. If the cross girders, or floor beams, are 15 feet apart and the roadway 12 feet wide, the capacity of each floor beam will be, by the above rule, 14,400 pounds, or say a wagon weighing 6 tons. If the bridge is packed full of cattle for a length of two panels, or say 30 feet, this is also provided for, and is the heaviest load that is likely to occur.

The trusses that carry the cross floor beams and joists of the roadway may be proportioned for a little less live load than the floor, for the reason, again, of the extreme unlikelihood of the whole bridge being fully loaded at one time. For bridges of 100-foot span, 80 pounds per square foot of floor is enough for the trusses. For 125-foot spans, 75 pounds is enough; for 150-foot spans, 70 pounds; for 175-foot spans, 65 pounds; and for 200-foot spans or over, 60 pounds is sufficient. In each case, the live load for the joists is 100 pounds per square foot, and the load for the cross floor beams is to be 80 pounds per square foot as before.

The length of the panels into which a truss is divided, depends on whether metal or timber joists are to be used. If these are of timber, the panels should not be more than 15 to 18 feet long, as long sticks are generally hard to get for renewals; and the longer the panels the more timber there is to renew per foot run of bridge. If metal joists are used there is no reason why panels of 20 to 23 feet long should not be used, and such panel length will be found to be economical; as then there are fewer panels, and fewer pieces for the bridge builders to make and erect. In this way the cost of a bridge with long panels and metal joists is rendered little if any greater than one with short panels and timber joists.

Timber joists should not be spaced more than 2 feet apart, and the floor plank should not be less than 2 inches in thickness. With joists 2 feet apart, the following sizes are proportioned to a live load of 100 pounds to the square foot of floor surface:

3 by 10 inch for 12-foot 3-inch span.
3 by 11 inch for 13-foot 6-inch span.
3 by 12 inch for 14-foot 9-inch span.
3 by 13 inch for 16-foot span.
3 by 14 inch for 17-foot 3-inch span.
3 by 15 inch for 18-foot 6-inch span.
3 by 16 inch for 19-foot 9-inch span.

These spans of from 12 feet 3 inches to 19 feet 9 inches, may of course be those of short span bridges of that length or the panel length of a truss bridge.

Steel joists, spaced 3 feet apart, may be used for the following spans or panel lengths, these being for the ordinary light sections rolled of the given depths.

Rolled beams 5 inches deep for 11-foot span.
Rolled beams 6 inches deep for 13-foot 6-inch span.
Rolled beams 7 inches deep for 16-foot span.
Rolled beams 8 inches deep for 18-foot 6-inch span.
Rolled beams 9 inches deep for 21-foot span.
Rolled beams 10 inches deep for 23-foot 6-inch span.
Rolled beams 12 inches deep for 28-foot 6-inch span.
Rolled beams 15 inches deep for 36-foot span.

With these spans the beams will deflect under the extreme load, but not enough to be objectionable for highway travel. These beams rest on the cross floor beams at the panel points, and these latter, for ordinary bridge spans, may be made of rolled beams also. For bridges with a 12-foot wide roadway, 12-inch beams will answer for panel lengths up to 17 feet; for a 14-foot roadway up to 13 feet; and for a 16-foot roadway up to 10-foot panel lengths. A 15-inch rolled beam will answer for panel length up to 27 feet for a 12-foot roadway, to 20 feet for a 14-foot roadway, and to 15 feet for a 16-foot roadway. These floor beams may be either suspended from the under side of the lower chords, or connected to the vertical posts above the lower chords. A good bridge can be built in either way, and one is no stronger for carrying travel than the other: for every point of a bridge is suspended in one way or another, and the point is to make the mode of suspension strong enough for its duty.

The floor plank should be laid squarely across the bridge, and never in more than one thickness, as the space between two thicknesses would hold water and dirt, which hasten the decay of the floor. To keep the hubs of the wheels from striking the trusses, there should be a line of guard timber bolted to the floor on each side of the roadway to hold the wheels at a safe distance. This, which it is well to have, renders unnecessary what is known as a hub plank, and a more unsightly object than a hub plank, warped out of shape and of no use, is hard to find. Also the abomination known as a lattice hub guard may well be discarded, as it is too low for a hand rail and too high from the floor to prevent a small animal from going under; and as a means of keeping hubs from the trusses, except by creating fear in the mind of the driver lest he should by chance hit it, it is not a success.

Just what to provide as a means of preventing a traveler from falling off the bridge is one of the unsettled points in the building of highway bridges. Five or six lines of iron rods from three-eighths to three-fourths inch in diameter strung through the center line of each truss are cheap, neat and effective. These can be joined together by threaded pipe couplings and tightened up against the end posts, through the center of which they pass. A wooden fence is as unsightly as the

hub plank, and is always out of repair. A gas pipe rail is better than the timber fence, but more expensive than either it or the iron rods mentioned above, while being no more effective than the latter.

The width of the roadway should not be less than 12 feet, and this only for bridges of less than 100 feet in total length. Where longer than this, two teams are apt to meet on the bridge, whereas on short spans one team can, if necessary, keep off while the other is crossing. For longer bridges, the width should be 14 feet in the clear, while a width of 16 feet in the clear is more desirable. A sidewalk is very seldom necessary on a highway bridge.

Now that we have determined the general dimensions of the bridge, and the load it is to carry, the next thing is to see that the structure will carry the loads for which it is designed. When iron first took the place of wood in bridge construction, the iron seemed to be a material so much stronger that too little iron was used, and for this reason many railroad and highway bridges had to be rebuilt. When steel took the place of iron, the same mistake was made, and engineers are now beginning to use steel more nearly as they would iron, and as they should in highway bridges. The steel used is not all like the steel in a razor or a handsaw, and the nearer it resembles iron in its properties the better. High-grade steel is too brittle to use in such structures, and if steel is subjected to high working stresses the bridge built of it is no stronger than one of iron, while the steel bridge is actually less rigid than the iron one under passing loads.

The working stress suitable for a tension member of a highway bridge is 12,500 pounds per square inch of the area of the cross-section of the member, whether of iron or of steel. This is one-fourth of the ultimate capacity of iron, and one-fifth of the capacity of soft steel, in tension; so that, while the deflection under a load will be the same in either case, the steel structure will be the stronger as far as the tension members are concerned.

Compression members should be strained 10,000 pounds per square inch of their section. This is about one-fourth of the ultimate capacity of either iron or soft steel in compression for very short columns. For long columns this working stress has to be reduced by one of the usual formulas for the purpose—Gordon's, for instance. As an illustration of the working of the formula for reducing the allowable stress on long columns the following may serve, as the columns are generally made of two channels latticed, for the vertical posts, and with the addition of a cover-plate for the top chord and end posts.

If a post is 1 foot long the allowable stress is 10,000 pounds per square inch. If made of two 5-inch channels the allowable stress becomes only 5,000 pounds per square inch, if the column is 21 feet

long. In the same way two 6-inch channels become worth only 5,000 pounds per square inch at a length of 25 feet, 7-inch channels at 28 feet, 8-inch channels at 33 feet, 9-inch channels at 36 feet, 10-inch channels at 39 feet, and 12-inch channels at 46 feet.

As a general thing, the diameter of the pins that connect the members of a bridge will run from one-third to one-half the depth of the channels used in the chords.

It is manifestly impossible, in the limits of a paper like this, to go into such detail as will enable the services of an engineer to be dispensed with. As in medicine, the doctor must be relied on. The point is for business men to determine the doctor's ability and reliability.

WHAT OUR BAD ROADS COST US.

By Clarence Coleman, Member of the Association of Engineers of Virginia.

[Read October 17, 1894.*]

In point of conception and invention, and in boldness of execution as a builder of the highest type of road known to science and art, the American of the nineteenth century stands pre-eminently in the front rank. Cities teeming with busy and thriving populations have sprung into existence, moved by the potent sign of the iron cross, made by these knights of the age of iron and steel. Fair fields are yielding rich harvests and paying their tribute to the commerce of the world in places that would have been inaccessible without the grand crusade of these modern knights, who have come, not like the knights of yore, leading their captives in their train and bearing their trophies on their shields, but, like the avatar of progress and science, leaving their indelible tracks in iron and steel emblazoned on the everlasting rocks.

The capitalist has been so lavish in creating and fostering these pathways of steel that to day 170,637 miles of railway in the United States represent in capital and funded debt the enormous and incomprehensible sum of $10,268,169,042, while the total amount of money in the United States on the 1st of July, 1893, was only $2,323,402,392. The general government has given 200,000,000 acres of the public domain and hypothecated its credit for $100,000,000 in the interest of these vast schemes. Certainly the arteries of the country have been nourished to the neglect of the veins, and, as in the physical constitution of the animal organization, these systems of circulation are so correlated that the very existence of the body corporate depends upon their synchronous development and action; so in the body politic, one system of internal improvement, created and magnified to the utter exclusion of its correlated part, destroys the equilibrium of its own creation and saps the very foundation of commercial prosperity.

It is no marvel that the human mind has been actually entranced by the magnificent possibilities of the modern railroad. It is no wonder that the tiller of the soil has plodded over miles of highway of miry consistency and almost fathomless depth to offer his life earnings at the altar of this nineteenth century fetich. We would not deprecate the advance and progress of this great factor in human civilization, nor can we deprecate its transcendent results. It is in accordance with

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the natural order of things that capital should seek investment in the most skillfully managed concerns and that it should avoid such ignominious failure as the management of our common roads presents. Had the improvement of our highways kept pace with the development of our railroads, we would have advanced the hands on the clock of progress another hundred years.

There is an aphorism of political economists to the effect that "The civilization and prosperity of a State is measured by the condition of its highways." Then, if we are prepared to recognize the value of good roads, we must, by an inverse process of reasoning, admit the cost of bad roads. If we could follow the differentiations of value in the one case, and of cost in the other, it would not be difficult to determine the results; but the problem presents a moral as well as a mathematical condition, and, while it would be interesting to enter into the domain of speculative philosophy and to apply the axiom of cause and effect to each particular ramification of this comprehensive subject, it will perhaps be better suited to our purposes to deal with actual facts as they unfortunately exist with us in this State.

To arrive at any definite conclusions in regard to these facts, it is necessary to institute some basis of comparison, and for this purpose I have selected France as having the most complete and perfect system of highways in the world, and exhibiting a degree of domestic, commercial, and financial prosperity which is in a great measure due to the equipoise of her system of internal improvements.

The State of Virginia comprises an area of 40,125 square miles, and has a population of 1,655,980, or 41.27 inhabitants for each square mile of area. France, with an area of 204,000 square miles and a population of 38,125,395, has 186.88 inhabitants for each square mile of area. Virginia has a total railroad mileage of 3,426.43, or 11.71 square miles of territory for each mile of railroad. France has a total railroad mileage of 24,018, or 8.49 square miles of area for each mile of railroad. Or, reasoning inversely, Virginia has 0.085 mile of railroad for each square mile, and France 0.116 mile of railroad for each square mile of territory. Virginia has 483.29 inhabitants for each mile of railroad, and France has a population of 1,586.53 to each mile of railroad; or Virginia has 10.92 feet of railway to each inhabitant, and France 3.32 feet to each inhabitant. Thus it is seen that France, with a little more than five times the area of Virginia, has about twenty-three times the total population of the latter—a little less than five times the poppulation per square mile; but, when we compare area with railway mileage, it is found that Virginia has only 3.22 square miles per mile of railroad in excess of France.

While, under the conditions of population in the two countries, the

last comparison seems anomalous, we will not need to seek far for the solution. When we consider that France is credited with 130,000 miles of macadam or stone highways, as against 689 miles for Virginia, we can appreciate the facilities of transportation possessed in that country outside of its railroads. Thus we would have for France 1.57 square miles of area for each mile of macadam road; and for Virginia 58.23 square miles for each mile of such road.

Again, a comparison of the population of the two countries with the mileage of macadam roads shows 293.27 inhabitants for each mile of macadam road in France, and 2,403.45 inhabitants for each mile in Virginia.

The French nation has certainly given the world assurance of what may be done in the construction and maintenance of highways, and the thrift and prosperity of those people stand as an everlasting monument to their efforts in this direction.

I am well aware of the probable opposition in this State to any plan that carries with it an increase of taxation. Since that eventful night on the 16th of December, 1773, when the partisans of old Samuel Adams went down to Boston Harbor and cast overboard the cargoes of tea, because tea meant taxation, the average American has had a most decided distaste for any visible form of taxation. He prefers to take his taxes like the child takes his medicine—disguised by aromatic essences, sweets and tinctures. He is, in fact, a species of sentimental ostrich, happy with his head in the sand, glorying in the homely saying, "Where ignorance is bliss, 'tis folly to be wise."

Forty years ago little or nothing was known of the pathology of germ diseases. Bacilli and bacteria were unknown. The physician struck out wildly and impotently, fighting a recognized malignant, deadly force, with no knowledge of its nature, and no power to resist its effects. And so it is with us. We are battling against an irresistible force in the shape of an invisible but not unfelt taxation, and we are calmly taking our rest in the shade of this deadly upas tree, oblivious of its noxious exhalations. We are annually paying a tribute to our bad roads, more onerous in its nature and more certain in its exaction than the oppression which incited Americans to rise and declare themselves free men. Shall we, who proudly refused to be the minions of government, remain forever the slaves of conditions, fettered with the shackles of our own inaction, and trammeled by the delusion of our hopes?

We plead poverty and inability to raise money for the betterment of our roads, and we have been annually expending, in money or labor, an amount which, under skillful and trained direction, would have placed our common roads upon a plane where at least they would not have been a reproach to our civilization.

As near as I can ascertain, there was expended in labor and money on roads in Virginia in the year 1893 an amount approximating $600,-000. So it can be readily seen that we are maintaining our own roads at immense expense, a very small proportion of this money and labor being used in the construction of permanent highways. The treatment may be said to be entirely palliative. Our roads are no better than they were the year before, and year after year this patchwork goes on with few permanent results.

Now, let us assume that during the past twenty years $300,000, had been spent on permanent improvement each year, and that the average cost of this work had been $1,250 per mile, we would have to-day 4,800 miles of permanent road, or 48 miles to each county in the State.

It is stated on good authority, that in Union County, N. J., by reason of the improved system of road construction and maintenance, farming lands are estimated at an average of $206 per acre, as against the average value of $65 per acre for the entire State.

It is not necessary that we should take such an example as that to show what we are paying for our miserable roads, but from very conservative figuring it can be demonstrated that we are paying enough to build and maintain a thorough system of highways throughout the State.

The assessed value of land in Virginia for the year 1893 amounted to $126,990,053. Now, it is certainly reasonable to assume that those values would be increased by not less than 20 per cent. with a good system of roads, which would give an increase in value of $25,398,-010.60, interest on which, at 6 per cent., amounts to $1,523,880.63. Now, that amount of interest represents the increment of a value we should possess under the desired conditions, and is, therefore, an annual charge against the State on account of bad roads.

I have figured, from the Statistical Abstract of the United States for 1893, that our principal crops of corn, wheat, potatoes, and tobacco amount to 1,265,782 tons of 2,000 pounds. I omit all other products, as lumber, mineral, and other crops, as an offset against that part of the crops which may be consumed at home, and taking 2,000 pounds as an average load and 10 miles as the average haul, we have 12,657,820 ton-miles, which, at 25 cents per ton-mile, represents $3,164,455 as the total cost of hauling all products to railroad or market. Now if, under the proposed conditions of good highways, the average load can be increased to even 4,000 pounds, then we are again paying each year $1,582,227.50 for our bad roads. But if we can haul the load of 4,000 pounds in four-fifths of the time required to haul the load of 2,000 pounds on the unimproved road, then we effect a saving in cost of $612,891, and that amount must be charged to the account of bad roads.

Then, taking the assessed value of all vehicles in the State at $3,051,783, and estimating annual depreciation under present conditions at 10 per cent., it is perfectly reasonable to assume that under the proposed condition 5 per cent. would cover depreciation, thus giving another charge of $151,586.90.

And finally, taking the assessed value of horses and mules at $13,495,932, and allowing that with good roads we can reduce the present cost of feeding and depreciation of stock to an extent represented by 3 per cent. of value, we have $404,877.96. Then we may sum up the annual cost of bad roads in Virginia as follows:

To interest on depreciation of land	$1,523,880 63
To additional cost of hauling	1,582,227 50
To loss of time in hauling	612,891 00
To depreciation of vehicles	151,586 90
To depreciation of horses and mules	404,877 96
Chargeable to bad roads	$4,275,463 99

Professor Eley has estimated that the loss per horse per annum on account of bad roads, amounts, in the United States, to $15, and, figuring on that basis for the State of Virginia, we would have 290,567 horses at $15, or $4,358,505, as the cost of bad roads, or $14.78 for each horse instead of $15. I thought his figures too high until I made these calculations, but I am now convinced that they are perfectly reasonable.

If my reasoning on this subject of the cost of bad roads is correct, we are losing in this State $11,713.60 for each day in the year, or $2.58 per annum for each unit of population. If we had the use of the money chargeable to bad roads, we could construct 1,710 miles of the best class of macadam roads each year, and in fifteen years our road system would be on a plane with that of France.

According to these figures, our bad roads are costing us $2,478,918.97, more than the total tax collected in the State, which, in 1893, amounted only to $1,996,545.02, or, considering the total taxable values of the State for 1893, we are paying a little more than 1.068 per cent. on that amount.

This invisible but insidious tax is none the less fatal to our prosperity because it is not gathered by the tax collector. On its list there are no delinquents, and there can be no evasion of payment. It reaches every class, creed and condition.

When the Roman emperors built thousands of miles of their magnificent highways all over Europe, they were conferring a priceless boon upon unborn nations, but they were, in fact, simply emerging from conditions which threatened to destroy their empire and extinguish their greatness. But, nevertheless, those roads remain to-day as exam-

ples of the highest art in highway construction, and the pretorian roads, that echoed to the tread of Cæsar's legions, now resound under the wheels of modern ordnance.

It is a sad travesty upon our nineteenth century civilization that here in Virginia, the mother of States, where thousands of miles of difficult railroads have been located and built, requiring the best skill of the engineer and the unstinted treasure of the capitalist, the locus of the first practical system of electric railway, a world teacher in the art of tunnel construction, with geographic, geological and climatic conditions supplemented by unparalleled economic resources, we are still in the very infancy of the art of building and maintaining our public highways.

"Though the mills of God grind slowly, yet they grind exceeding small;" and so, with the accumulated grist of our four hundred years, gained under the nether stone of experience, we are ready to rise, and, with the same spirit which prompted our forefathers to wrest from King John the great charter of human liberty, we are to-day prepared to set about the establishment of that equilibrium in our system of internal improvement which is no less essential in political than in natural economy. It is in evidence, and attested to-day by the presence of representative men from every part of this broad commonwealth, that the term of our bondage is closing and the day-star of a brighter era has appeared.

I am filled with faith as to the result of the work of this Convention. It is the first time in the history of our State that such an assemblage, for such a purpose, has ever been convoked, and it has come to pass as a necessity born of conditions. I know my people and I honor their history and traditions, which teach me that when once they have determined upon the accomplishment of a purpose there is no looking backward until the goal is reached.

Through me, their unworthy representative, and my worthy colleagues, the Association of Engineers of Virginia sends you greetings and Godspeed in the great work you have undertaken, and I know that this Convention, carrying with it the good wishes of every Virginian who loves his State, will address itself to the task of reform in road laws with a resolute determination that recognizes no such word as "fail."

PORTLAND CEMENT CONCRETE AT FORT POINT.

By George H. Mendell, Member of the Technical Society of the Pacific Coast.

[Read May 4, 1894.*]

The following notes and remarks result from recent experience in construction of fortifications in concrete, near Fort Point, in this harbor. They necessarily have a local flavor, and for this reason—and as affording examples of the cost of a particular kind of work in our neighborhood—it is hoped that they may possess some interest.

Concrete is a hackneyed subject about which it may be thought that little can be said that has not been said before. Yet it is always interesting by its varieties of fabrication and application, and is not at once exhaustible. Moreover, there is always something suggestive in accounts of local operations kindred to those in which we are or have been engaged.

Concrete is an agglomeration of the commonest fragments of stone and sand converted into a monolith by addition of water mixed with other common things, namely, impure clay and carbonate of lime, calcined and pulverized. The cementing material has the special quality of hardening in water, from which it derives its name—hydraulic cement.

These materials, mixed in due proportions, shortly become a solid mass, which grows in hardness and strength for months. This is concrete. It has a wide application and usefulness. It is the pavement under our feet, the foundation or walls of the house in which we live. the arch or lintel which covers our heads, the reservoir which impounds the water supply, the dam which directs or divides a river, the breakwater which withstands the blows of the waves. It bears steady loads of 10 tons or more per square foot, and 200 tons or more per square foot are required to crush it. The rupturing or tensile strain may be 100 or more pounds per square inch. These powers of resistance, both compressive and tensile, vary with the character and proportions of the ingredients, and they may be adjusted to the requirements of any special construction.

The art of compounding the ingredients is simple, and may soon be learned by men of ordinary intelligence. The ingredients, so far as they are natural, are found everywhere, and wherever found they are com-

* Manuscript received March 18, 1895.—*Secretary, Ass'n Eng. Socs.*

mon and cheap. The artificial ingredient, the least in quantity—namely, cement—is comparatively costly, and for this reason it needs to be used with judgment and discretion, not too lavishly.

When we take account of the many varieties of sand and stone in the world, ranged by mineralogical composition or physical qualities of form, size, weight and hardness, and the differences in cement due to process of manufacture and character of ingredients, and reflect that every variation in material or process of manufacture leaves its mark upon the final product, we see that concrete is not one but legion.

Even here, with a limited range of variety in materials, the term is common to many products which vary much in cost, value, strength and applicability.

It is an important part of professional knowledge and judgment to select from these possible concretes the one that is best adapted for the construction in hand. We may say the best and the cheapest, for the engineer is bound to do his work economically. He must not use ten-dollar concrete in applications where six-dollar concrete would do as well or better. It is not paradoxical to say that a meagre concrete is, for some purposes, better than a more costly product richer in cement.

This matter touches the ethics of the engineer's profession. We are bound to do work well, and are also bound to do it as economically as possible. A mistake of too costly construction, made by an engineer of experience, may be likened to a misdemeanor in law, or worse.

The desire to make the work certainly good enough, naturally suggests liberal use of cement. There are circumstances where free use of cement is judicious and necessary; but in many cases the builder may find reward and economy in a careful study of materials in their bearing upon the cost of masonry.

There are standing at the door of the office, at the Fort Point Works, two blocks of concrete of Portland cement, the matrix being one cement to five sand. These blocks are samples of a cheap and fair concrete, about two cubic yards to a barrel of cement. It weighed 148 pounds to the cubic foot when three months old, which is more than the weight of a richer product. In a construction where weight is particularly required, and where there is no great strain, and plenty of time to strengthen, this character of concrete might be as fit as a richer compound.

The quality of concrete is generally defined by the proportions in volume of the solid ingredients, the cement being taken as unity. When a barrel of cement is taken as the unit, there is danger of confusion of ideas, for the reason that a barrel may be taken to mean either one of several volumes. The cubical contents of a barrel of Portland cement have been found to vary from about $3\frac{1}{8}$ to about $3\frac{1}{2}$ cubic feet. The cement is packed more or less closely by different makers. The gross

weight is found to be, with a little variation, 400 pounds; the net weight about 375 pounds per barrel. When poured out loosely on a platform, and measured by means of a cubical box, not shaken, the contents of a barrel make about 4½ cubic feet. Converted into a paste by addition of about two cubic feet of water, the volume becomes about four cubic feet.

If we take a formula for our mortar of any given proportion of sand, say three volumes to one, the amount of sand for a barrel of cement may be about 10, or 12, or 13½ cubic feet, accordingly as we take the volume of a barrel of cement to be 3½—as it is when compacted—or 4 feet in paste, or 4½ feet in loose volume. The clearest formula is expressed in a given number of cubic feet, both of sand and rock, to a barrel of cement.

The volume of paste is the best, we may say the scientific, unit, but it may be either of the three under the condition that it be defined. In the operations at Fort Point three parts of sand are understood to be 13½ cubic feet per barrel of cement. Thus understood, the proportions of one cement, three of sand, and eight of rock and gravel, which constituted the formula usually employed, gave a volume of concrete in place about equal to the volume of the stone used, that is, for one barrel of cement, 36 cubic feet of concrete, or 1⅓ cubic yards.

The quantity of water required with dry materials is about four cubic feet per barrel of cement. The rule is to mix the concrete with a minimum of water, and to tamp it until water gathers on the surface. In hot, sultry days, the evaporation being rapid, it was found necessary to mix with more water. The stone used was quarried at Angel Island, in sizes suitable for a "Gates" crusher, delivered on the wharf at Fort Point, hauled in wagons to the crusher, which delivered it to the mixer, into which all the ingredients were fed automatically. The mixing was continuous. The concrete was delivered, at the mouth of the revolving cylindrical mixer, into cars holding twenty cubic feet. When a car was filled, the door of the mixer was closed for a minute, during which a second car was put in place, and during this minute the concrete accumulated in the mixer.

This continuous mixer has obvious advantages, but there is difficulty in automatically delivering materials in stated proportions. The original arrangement of the supply hoppers was modified, and bettered, as a result of our experience, so that at last the desired result was measurably attained.

The cost of concrete per cubic yard, in place, distributed among the ingredients was, when made in mixer, as follows:

Portland cement	$1 82
Stone	1 40
Gravel	35
Sand	29
Water	4
Crushing, mixing, transporting and ramming	80
Total	$4 70

The cars were pushed by two men to the place of deposit, a variable distance of 100 to 200 yards, and discharged from a tramway through a height which was 30 or more feet at the beginning, diminishing to 3 or 4 feet at the close. The concrete was then shovelled into wheelbarrows, and wheeled 20 to 40 feet. The structure is a great mass, being about 60 feet long, 40 feet wide, and 30 feet in height.

The following is a record of several weeks of work:

MATERIALS USED.

Broken stone	1,500	cubic yards
Gravel	475	"
Sand	572	"
Portland cement, 1317 barrels	220	"
Total	2,767	cubic yards.

Volume of concrete measured by cars of 20 feet capacity, 2,433 cubic yards. Volume compacted, 1,825 cubic yards.

A car-load of 20 feet of loose concrete was found, in different experiments, to make 15 to 15½ cubic feet, compacted. The quantity of compacted concrete, 1,825 cubic yards, is practically two-thirds of the loose volumes, namely: 2,767 cubic yards. No account of water is taken here.

Gravel and sand are, to some extent, interchangeable, so far as sizes are concerned, and, to bring the results just given into relation with the formula, we need to class about 100 yards of gravel, more or less, as sand.

The cost given—namely, $4.70 per yard—includes no charge for timbering, or for incidental expenses, other than the pay of the foreman and the men directly employed. The day is eight hours, the pay of foreman $4.00 per day, and of the men $2.00. Cement cost $2.50. The empty barrels furnished fuel.

Another example of concrete, placed in smaller masses—under very different circumstances—is found in the piers of the steel bridge at Alameda.

The cement was furnished in this city to the contractor, who had no pecuniary interest or risk in it, except to transport and care for it. The

cost of cement was $2.93 per barrel. The quantity of concrete distributed in five piers was 2,352 cubic yards, consuming 1,940 barrels of Portland cement. One barrel gave 1.2 cubic yards in place. The contractor was paid $4.90 per cubic yard for making and placing concrete, and supplying all labor and materials, except cement. The cost of the concrete to the United States, including service of an inspector, was $7.36 per cubic yard. A continuous mixer was used.

The following accounts of experiments are in our records:

FIRST CASE.

1 barrel of Portland cement, measured loose	$4\frac{5}{12}$	cubic feet.
Water added	2	"
Volume of stiff paste resulting	4	"
Moist sand of medium coarseness added	$10\frac{1}{8}$	"
Water added	2	"
Volume of quite wet mortar resulting	$9\frac{1}{8}$	"
Gravel, sizes $\frac{3}{4}''$ and less, added	$36\frac{1}{2}$	"
Amount of loose concrete	$45\frac{1}{4}$	"
Amount tamped in place	$37\frac{1}{2}$	"

Remark:—There seems to be a suspicion of error in the volume of mortar, to the extent of one measure—a cubic foot box. Volume of mortar perhaps ought to be $10\frac{1}{8}$ instead of $9\frac{1}{8}$.

SECOND CASE.

1 barrel of cement, loosely measured	4.58	cubic feet.
Water	1.75	"
Volume of paste	3.8	"
Sand 3 volumes of paste	11.4	"
Water	2.5	"
Volume of mortar,	12.3	"
Gravel, in sizes of beans and smaller	36.9	"
Volume of loose concrete	43.23	"
Tamped volume not measured.		

THIRD CASE. BARREL OF $3\frac{1}{2}$ CUBIC FEET.

Volume of loose cement	$4\frac{1}{2}$	cubic feet.
Water	$1\frac{11}{12}$	"
Volume of paste	$3\frac{5}{6}$	"
Sand	$13\frac{1}{2}$	"
Water	2	"
Volume of mortar	14	"

REMARKS.

The varieties in forms and sizes of materials are so great, and personal equations are so different, that rules as to quantities to result from combinations of materials in different proportions, can not be made precise. Each person is apt to find the rules derived from his own experience to differ from those established by others. Measurements of materials vary

with the manner of making them. The writer has chosen to make all measurements loose—that is, the vessels are not shaken to settle the materials to a smaller volume.

Moreover, the void spaces, howsoever the measurements be made, vary with the sizes and variation in sizes. This is illustrated in the first case, in which the voids in 36½ cubic feet of gravel are more than filled with 9⅛ or 10⅛ (if the latter be correct) of mortar. Ordinarily, voids are 33 to 40 per cent. In this case they amount to about 25 per cent., and are accounted for by the fact of variation in sizes from ¾-inch to that of bird shot.

The advantage of graded sizes in broken stone is clearly shown. The voids being thereby reduced, a given quantity of mortar will take more stone and make more concrete.

According to the experience of the writer, a matrix of 10 feet of loose sand to 1 barrel of Portland cement will suffice for about 27 feet of suitable broken stone, and will make about 1 yard of concrete in place. If we use 13 to 14 feet of sand we can make 1⅓ cubic yards of concrete to a barrel. With 22 feet of sand we ought to get about 2 yards to a barrel.

CHARACTERISTICS OF CEMENTS.

Particular care was had in selecting the sand used in this work. It is believed to be the best that can be conveniently obtained for concrete. It is coarse, running into gravel, mixed with fine—clean and sharp. It was collected on the beaches adjacent to Fort Point.

The usual tests for tensile strength, by breakage of briquettes, made neat of salt and fresh water, and with different doses of sand, of ages from 1 to 7–28 days, and varying to a year, were kept up during the progress of the work, and recorded.

The tensile record, particularly with neat briquettes, is good for all cements used. The tests of briquettes dosed with sand, seem to be more discriminating than with neat briquettes. It is observed that while two cements gauged neat may not show great differences in tensile strength, yet notable variations appear when gauged with sand, the fine ground cements showing greater strength than the coarser.

The sieves used for determining fineness were bought in this city. They are graded by the maker as 50–70–100 to the lineal inch. In fact the first two contain respectively about 2,250 and 4,200 meshes to the square inch. They are referred to in this paper under the maker's grades. The meshes in the third could not be conveniently counted.

The sieves being arranged in column, the coarsest on top and the finest on the bottom, a charge of 1,000 grains of cement is placed in the upper sieve, and all are duly shaken. This operation completed, you

have 4 portions graded in order of fineness, which are then separately weighed.

The annexed table represents the mean results of several tests with each of six brands of cement of good standing.

TABLE.

Cements.	Passed 50.	Passed 70.	Passed 100.
No. 1	980	953	869
" 2	929	844	736
" 3	989	948	833
" 4	925	863	771
" 5	969	895	764
" 6	927	873	788

The sieve wires are respectively Nos. 35, 37 and 40, American gauge.

The respective mesh areas of the 50 and 70 sieves, so-called, are approximately 3,600 and 8,500 to the square inch.

If there were 100 meshes to the inch in the 100-sieve, the mesh area would be 21,000 to the square inch.

There is some ground to think that the mesh area of this sieve is not far from 17,000 to the square inch.

The portion of one of the fine ground brands which passed the 100 sieve, was made with three parts of sand, by weight, into eight briquettes, and broken at ages of 127 to 129 days. The tensile strength per square inch varied between a minimum of 387 pounds to a maximum of 442, with an average of 417 pounds. The same cement, ungraded, with three parts of sand, 120 days old, gave a mean of 333 with thirty briquettes. The portion which, having passed the 70 sieve, was refused by the 100 sieve, was similarly dosed with sand and made into four briquettes, which broke at 127 days with strain per square inch of 57 pounds–65–75. The fourth briquette broke without strain. The portion which, having passed the 50 sieve, was refused by the 70, treated in five briquettes at the same age, broke at 48 to 58 pounds. Three briquettes, with three parts of sand, left in moulds thirty hours, broke on removal or fell apart when placed in water.

This experiment suggests, so far as it goes, that in the usual applications with sand, the valuable part of cement is found in the finest grains. The next grade in fineness shows little comparative strength, the next still less, and the coarsest none at all. Yet the coarsest grains, when sufficiently pulverized, develop hydraulicity. It remains to determine whether or not time can add value to the coarser grains. A sample was recently sent for test, which is represented to be a finer grinding of one of the coarse brands of the table, to about the scale of the finest. It showed great improvement in strength by finer grinding.

The writer received from a manufacturer on the continent of Europe the following statement, which is here given for what it is worth:

"Dividing Portland cement into four grades of fineness, by sieves of 324-900 and 5,000 meshes to the square centimeter, which correspond to 2,100, 5,800 and 32,000 to the square inch, it is found that while the finest, No. 4, is most active, yet No. 3 will equal it in strength in reasonable time; No. 2 will, after a year in water, form a compact mass, with, however, no great power of resistance. No. 1 will always remain inert."

According to this rule, the best examples found here show at least 5 per cent. of useless grains, while some brands show 15 per cent., or more.

It is claimed for finely ground cements that they take more sand. This means that a less proportion of cement to sand will give an equally good mortar.

Assuming, for the purpose of illustration, the numbers already quoted, namely, 417 pounds for sifted and 333 pounds for unsifted, to express the relations between these samples, it would appear that the first, with five parts of sand, and the second, with four parts, would produce mortars of equivalent tension. So far as this goes, the value of the first cement is about one-fourth more than that of the second. Without insisting upon the exactness of this deduction, we may at least see that a builder can afford to pay something for fineness.

It was found that while very fine ground cement gave the best results when mixed with sand, yet a neat briquette made of the finest ground part of a cement is, at least at some ages, not generally so strong to resist tension as a neat briquette made of the same cement ungraded.

A notable difference is observable in the quality of packing and the soundness of barrels in which cement is imported. A good barrel suggests good contents. Bad barrels involve loss both in cooperage and in the quality of the cement. As a general rule, a preference is to be given to the best packages. The best are tongued and grooved.

It is to be said, for all the standard brands known to the writer, that no indication of free or uncombined lime has been detected in any of them.

HAND-MADE CONCRETE.

Much the greater part of the concrete was made in a mixer, yet a considerable quantity was mixed by hand. During August, 1892, a gang of twenty men was employed, under a foreman, in hand mixing. The foreman received $4.00 per day, and the men $2.00 for eight hours.

The average daily output was 45 cubic yards, and the cost almost exactly $1.00 per yard for labor of mixing and placing. The work was done in batches of 4 barrels of cement, and 144 cubic feet of broken rock and gravel, giving the same amount of compacted concrete.

The manner of making was this, namely: The materials were grouped in the most convenient manner about a large platform of plank, upon which the mixing was done. Upon this platform the stone and gravel, measured in wheelbarrows, were placed in a stratum of even thickness. Upon this sand was wheeled, and leveled with a straight-edge. The cement, also leveled, formed the top stratum. Water was added in the turning. The materials were turned twice, and carefully dispersed in the act of turning, which is important. A third turning resulted from shoveling into wheelbarrows, and a fourth in its distribution over the building. The mass of the building was large. There was no ascent in wheeling, and the distances were short.

The men were a picked lot—a sort of evolution from a great number of laborers; and, taken altogether, the circumstances were exceptionally favorable.

It will be remembered that the labor cost of making by machine and placing has been given at 80 cents, which included crushing rock. Making allowance for the cost of crushing, the result of comparison of machine and hand making, the latter under the most favorable circumstances, gives the result that hand-made costs about 50 per cent. more than machine made, in the item of labor.

Doubtless, under average conditions the comparison would be more favorable to the mixer.

The weight of concrete three months old, as made at Fort Point, is 143 pounds per cubic foot.

REGULATIONS GOVERNING THE ERECTION OF BUILDINGS, APPLICABLE TO CITIES HAVING A POPULATION OF FROM 10,000 TO 30,000.

COMPILED BY THE ASSOCIATION OF ENGINEERS OF VIRGINIA.

Approved and adopted June 23, 1894, by the City of Roanoke, Va.

1. *Be it ordained by the Common Council for the City of Roanoke.* That before the erection, construction, alteration or extension of any building or part thereof in the city is begun, the owner, builder, or architect shall submit to the City Engineer a clear statement of the material to be used and the mode of construction of the proposed building or alteration, with the plans and specifications, said statement to be in writing on suitable blanks to be furnished by the City Engineer for that purpose, and no building or part thereof, alteration or extension shall be commenced until the owner or builder shall have received from the City Engineer a certificate of permit specifying the material of which the outer walls and outer covering of the roof of said building is to be composed, the street upon which and the distance therefrom at which said building is to be placed, a copy of which shall be filed in the office of the City Engineer under the date of its issue, and said permit shall be issued by the City Engineer after examination of the plans and specifications or detailed description; provided they are in conformity with this ordinance. If a building or alteration or extension of a building shall be begun without said certificate of permit, the builder and owner shall both be deemed to have violated this ordinance.

2. It shall be the duty of the said City Engineer to examine the condition of all buildings undergoing alteration or being erected within the city limits, and to serve notice in writing upon both the contractors and builders and upon the owners or architects of such structures as he may deem to be unsafe and insecure by reason of the mode or manner of construction, or the material used in the construction thereof, and shall order such changes in the mode or manner of construction as he shall deem necessary for public safety.

3. The said City Engineer is hereby empowered, whenever in his judgment occasion may require, to enter into and upon any building, premises, staging or other structure, for the purpose of examining the same with reference to its safety and of attending to the performance of his duties as required by law.

4. Any wooden building already constructed in the fire limits, which may hereafter be damaged, may be repaired, provided, the build-

ing was a good sound one previous to said damage, and provided, that it is not more than half destroyed, exclusive of the foundation. The City Engineer shall determine the amount and extent of such damage.

5. The City Engineer may permit temporary wooden structures in connection with the erection of buildings; said permit to be given in writing for a specified time.

DEFINITIONS.

6. In this ordinance the following terms shall have the meanings respectively assigned to them:

By the term "City Engineer," is meant such officer or officers as is designated by the City Charter or general ordinances of the city to inspect the erection of buildings.

7. "Alteration" means any change or addition.

8. "Cellar" means a lower story, of which one-half or more of the height from the floor to the ceiling is below the level of the ground adjoining.

9. "Foundation" means that portion of a wall below the level of the street curb; and where the wall is not on a street, that portion of the wall below the level of the highest ground next to the wall; but, if under party or partition walls, may be construed by the City Engineer to mean that portion below the cellar floor.

10 "Party wall" means every wall used, or built in order to be used, as a separation of two or more buildings.

11. "External wall" means every outer wall or vertical enclosure of a building other than a party wall.

12. "Partition wall" means any interior wall or masonry in a building.

13. "Partition" means any interior wall in a building other than a partition wall.

14. "Repairs" means a reconstruction or renewal of any existing part of a building by which the strength is not reduced nor the fire risk increased, and which, in the opinion of the City Engineer, is not made for the purpose of converting the building, in whole or in part, substantially into a new one.

15. "Thickness of a wall" means the minimum general thickness of such wall.

16. "Stories" are counted from the first tier of beams at or above the level of adjoining ground or sidewalk.

17. "Half story" means that portion of a story immediately under the roof, whose greatest inside height shall not exceed five feet from the floor to the spring of the roof.

18. "Wooden building" (within the fire limits) means any building any structural part of whose outside wall is of wood.

19. "Wooden building" (outside the fire limits) means that portion of any building which has a wooden exterior.

20. "Building of brick or other incombustible material" means any building the structural part of whose outside wall is of such materials.

21. "Block of dwellings" means a series of two or more houses used mainly for dwellings, such houses being separated by partition walls and having separate entrances and stairways.

22. "Shed" means a structure not exceeding one story in height, at least one of whose sides shall be open.

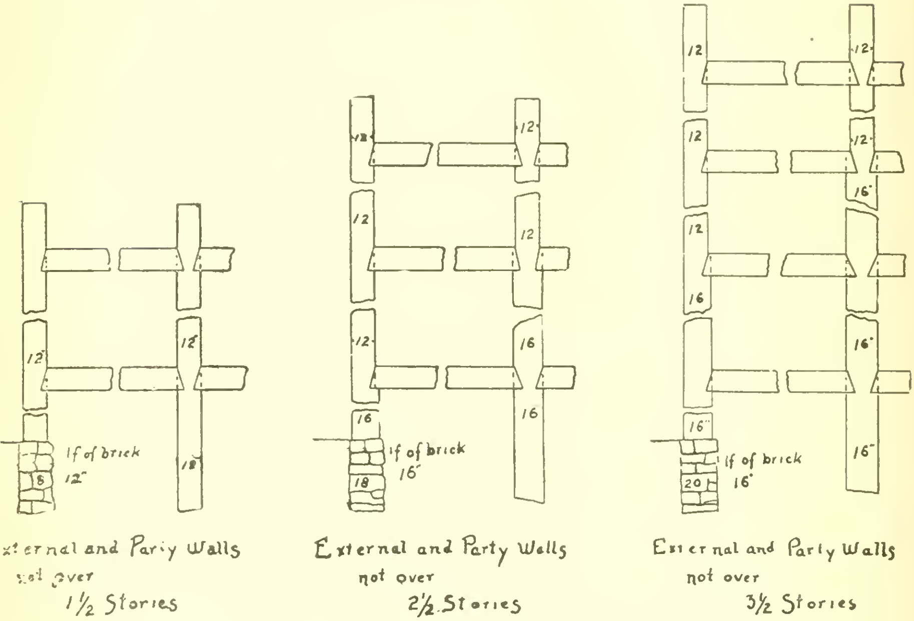

Plate 1*a*.—Brick Buildings other than Dwellings.

23. "Cement mortar" means a mortar composed of good, fresh cement, and clean, sharp sand. When deemed advisable, a small amount of lime may be used, not, however, exceeding the quantity of cement. When used in foundations the amount of lime must not exceed one-fourth the quantity of cement.

WALLS OF BRICK BUILDINGS.

24. The thickness of walls shall not be less than is indicated by the diagram on Plate I. The maximum load which shall be allowed on any foundation or masonry shall be as follows: Earth foundations, three tons per square foot; rock, ten tons per square foot; concrete, ten tons

per square foot; common rubble, four tons per square foot; first-class rubble, ten tons per square foot; block stone, twenty-five tons per square foot; common brick and lime, six tons per square foot; common brick in cement, ten tons per square foot; pressed brick in cement, fifteen tons per square foot.

25. All walls over one hundred feet in length without cross-walls or buttresses shall be increased four inches in thickness.

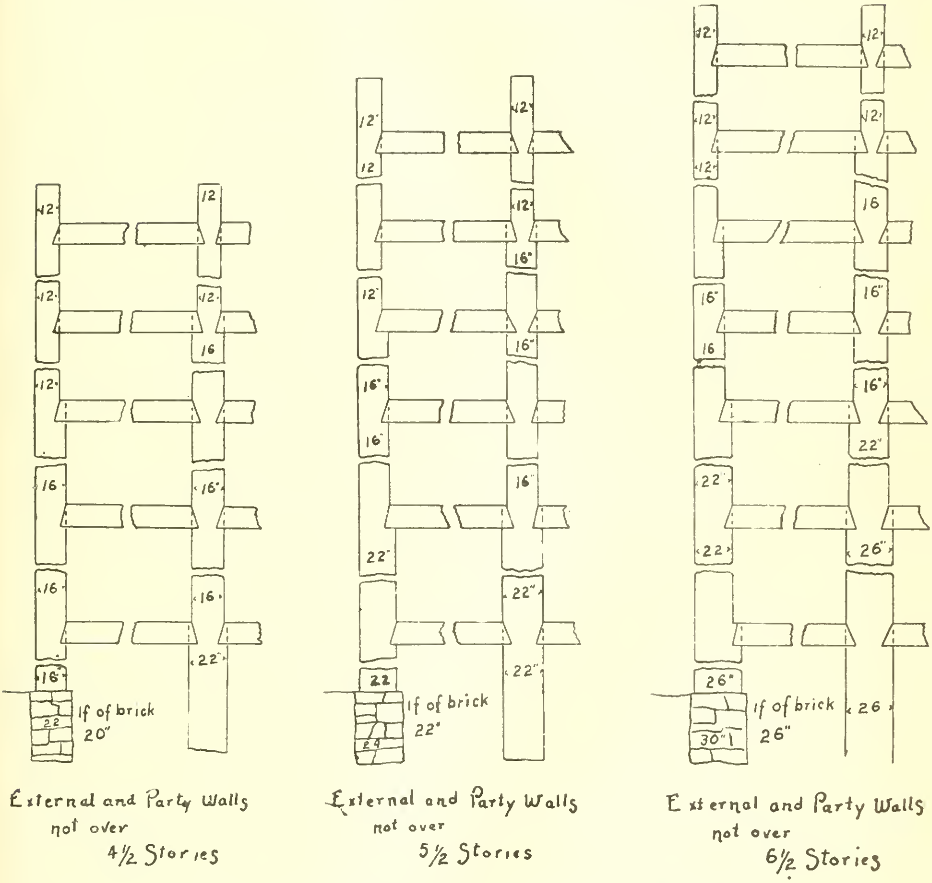

PLATE 1*b*.—BRICK BUILDINGS OTHER THAN DWELLINGS.

26. When hollow walls are used, the air spaces are not to be included in the thickness required.

27. Slots and chases in the walls shall not be allowed to come within four inches of the opposite side of the wall, and no two slots shall be within eight feet of each other.

28. The walls of all brick buildings over three and one-half stories

in height shall be well laid in cement mortar. All other brick walls shall be well laid in the same or in some other suitable mortar.

29. If any brick building already built, or which may hereafter be built, shall be enlarged, raised or built upon, it shall be made to conform to the requirements of this ordinance.

30. Whenever more than half the area of any brick wall is occupied by window or other openings, the constructive framework and casings (except ordinary window frames) of said openings shall be of iron or other incombustible material, and the remaining portions of the wall shall be suitably thickened.

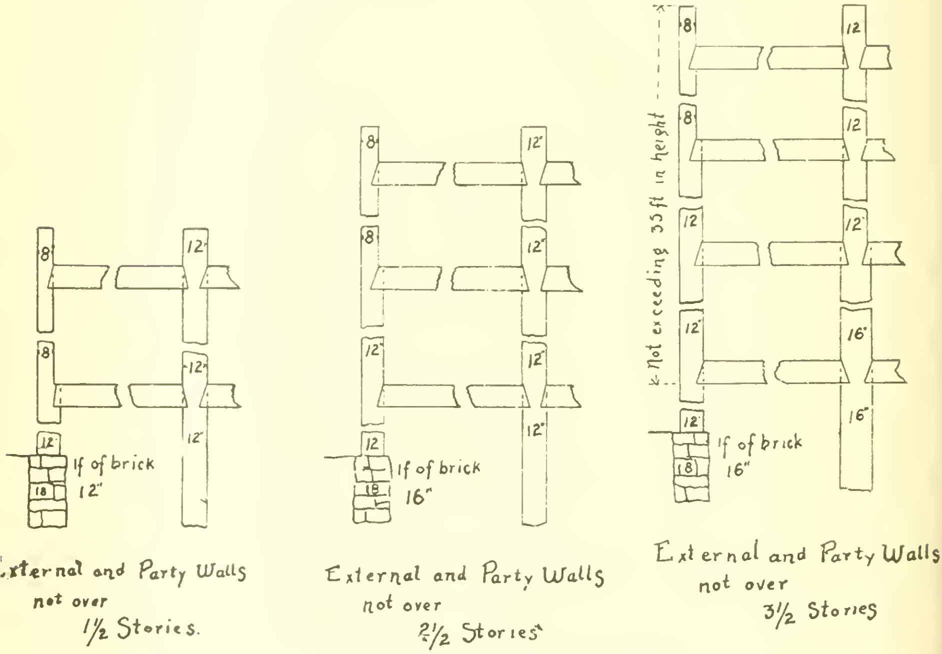

PLATE 1c.—WALLS OF BRICK DWELLINGS.

31. No wood lintels or beams of over six-foot span shall be used to support brick or masonry walls.

32. No brick or stone wall of any description shall be carried on wooden pillars.

33. All brick walls shall be well bonded at least every sixth course throughout the thickness of such walls.

ASHLAR FACING STONE.

34. No ashlar shall be less than four inches thick, and shall have a bond stone running through the thickness of the wall at least once in

every square yard of surface of wall; and it shall not be considered a part of the wall when reckoning the thickness of walls as per paragraph on "Walls of Brick Buildings," unless it be eight inches or more in thickness, in which case all but four inches of its thickness may be reckoned as a part of the wall; provided, however, that in buildings used as dwellings only ashlar eight inches thick may be used in facing brick cellar walls above grade without bond stones.

FOUNDATIONS.

35. The thickness of foundation walls shall not be less than is indicated by the diagrams of such walls on Plate I. The diagrams are intended for ordinary conditions only. Whenever foundations are unusually deep or serve as retaining walls, etc., the thickness must be proportionately increased.

36. All foundation walls shall be properly bonded and well laid in cement mortar. Frame dwellings may have foundations laid in lime mortar.

37. Broad and heavy footing courses are to be provided wherever the condition of the soil or the height of the building may demand them, and in all cases brick foundations shall be started on such footing courses.

38. No wooden post shall be used in any cellar as a structural support. Brick piers shall have footing stones not less than six inches thick and projecting not less than six inches all around.

WALL ANCHORS.

39. The front, rear, side and party walls of any building hereafter to be erected shall be anchored to those adjoining every six feet of height by T anchors made of one and one-quarter inch by three-eighths of an inch wrought iron, except when said walls are carried up together and well united and bonded at the point of contact. The said anchors shall be built into the side or party walls not less than thirty inches, and into the front and rear walls within four inches of the outside of the front and rear walls, so as to secure the front and rear walls to the side, end or party walls. The front, rear, side and party walls shall be anchored to each tier of beams at intervals of not more than six feet apart (except in cases of mill construction, when each timber shall be well anchored), with some form of releasing anchor approved by the City Engineer.

CHIMNEYS AND SMOKE PIPES.

40. No chimney or smoke flue shall be built with less than eight-inch walls below the roof line unless lined with terra-cotta pipe. And

when not so lined, all interior joints shall be struck smooth, and no pargeting will be allowed. No chimney-top shall be less than four feet above the roof (for flat roof) nor below the ridge of any pitched roof, unless more than fifteen feet from same.

41. Flues in party walls shall not extend beyond the center of the wall. Joint flues in party walls shall be separated by four and one-half inches of brick work for their entire height.

42. No chimneys shall be started or built upon any wooden floor or beam, and in no case where the breast of chimneys shall project more than six inches shall it be commenced in any wall or supported by corbelling, but shall be started from the foundation.

43. Flues for boilers and furnaces for manufacturing purposes shall be built of brick or metal of such size and height as may be determined by the City Engineer.

44. All hearths shall be supported by arches of stone or brick or by iron construction, and no chimney in buildings already erected or hereafter to be built, shall be cut off below and supported by wood, but shall be wholly supported by brick, stone, iron or steel. The back of no fireplace or grate shall be less than eight inches from the opposite side of the wall.

45. Depositories for ashes shall be built of brick or other fire-proof material.

46. In no building, whether the same be a frame building or otherwise, shall any wooden girders, beams, timbers or other wood-work be placed within six inches of any hot-air or other flue unless protected by brick, mineral, wool or their equivalent, in which case the distance may not be less than two inches, and in no case shall any timber or wood-work be built into the brick-work of any chimney or smoke flue, but shall be framed around same as in Section 55.

47. No smoke pipe in any building with wooden or combustible floors or ceilings shall hereafter enter any flue unless the said pipe shall be at least twelve inches from either the floors or ceilings or side partitions, and in all cases where smoke pipes pass through stud or wooden partitions of any kind, whether the same be plastered or not, they shall be guarded by either a double collar, made with terra-cotta on the outside and metal on the inside, with at least one inch air space and holes for ventilation between, and extending through the partition; or by being enclosed by a terra-cotta thimble, with at least six inches of brick-work all around for full thickness of the studding; provided, however, that the City Engineer may allow a less distance than twelve inches from a smoke pipe to wood-work if the latter is protected by a shield of tin-plate or other suitable material not less than one inch from the pipe and two inches from the wood-work.

48. Whenever a smoke pipe passes through the floor it shall be encased with a double collar, as above specified, except that the collar shall be entirely open at the bottom and have holes only at the top.

49. Furnace smoke pipes shall not be less than eighteen inches from all wooden floors or partitions.

50. Tops of all furnaces shall not be less than ten inches from the floor joists above, and shall be covered with two inches of sand or otherwise protected.

STEAM BOILERS AND PIPES.

51. No high pressure steam boiler shall be set without a permit made out in due form by the City Engineer; and no such boiler shall be set inside or under any city or town building, any jail, schoolhouse, church, theatre or other place of public assembly, any hotel, office or apartment building without a special permit from the City Engineer, requiring annual inspection of the boiler by competent inspectors, reports of such inspections to be regularly filed with the City Engineer.

52. All steam pipes passing through wood-work shall be protected by an iron collar, with an air space between. All steam pipes shall be supported by iron brackets or hangers.

WOODEN FLOORS.

53. The size and spacing of floor joists, except for "mill construction," must be not less than provided for in the following table:

Span not more than	Least size.	Greatest distance on centers.	Least number rows of cross bridging.
12 feet	2 inches by 8 inches	16 inches	1
15 feet	2 inches by 10 inches	16 inches	1
18 feet	2 inches by 12 inches	16 inches	1
20 feet	2 inches by 14 inches	16 inches	2
20 feet	3 inches by 12 inches	16 inches	2
25 feet	2 inches by 14 inches	12 inches	3
25 feet	3 inches by 12 inches	12 inches	3

The maximum fibre strain which shall be allowed in any beam, joist, girder or tie shall be as follows: Rolled steel, 16,000 pounds per square inch; rolled iron, 12,000 pounds per square inch; cast iron, 5,000 pounds per square inch; yellow pine (Carolina or Georgia), 1,350 pounds per square inch; Virginia pine or spruce, 1,000 pounds per square inch; oak, 1,200 pounds per square inch.

54. In all cases the joists are to be doubled and spiked under partitions and around openings, and supported on suitable hangers, and are to be properly bridged; and where more than two stories of partitions come over a span, a suitable truss is to be formed.

55. In no building shall any wooden girders, beam or timbers be placed within one inch of the outside of any chimney or wall outside of any flue.

56. All wooden beams and other timbers in the party wall of every building hereafter to be erected or built of stone, brick or iron shall be separated from the beam entering in the opposite side of the wall by solid mason work of at least four inches.

57. The ends of all joists in the brick walls shall be so beveled that no level portion of the top of such joists shall enter into the brick-work. All joists shall rest at least four inches on the brick-work.

BRICK WALLS IN A BLOCK OF DWELLINGS.

58. Every dwelling in a block of dwellings shall be separated from the one adjoining by a brick party wall running from front to rear. Such walls shall be without openings, and shall be built out to boarding of sides, roof and cornice. The thickness of such walls shall be as specified in this ordinance.

WOODEN SILLS.

59. The sills of all wooden structures over one story in height shall be not less than 4 x 6 inches. The sills of all wooden structures which are set at a greater height than one story above grade shall be anchored to the brick-work below.

STUDDING.

60. The studding of outside walls of all wooden structures three stories in height shall be not less than 2 x 5 inches, set not more than sixteen inches on centers. And the studding of outside walls and bearing partitions in any wooden structures shall be not less than 2 x 4 inches, and set not more than sixteen inches on centers.

61. Every building 50 feet wide or over (other than a dwelling house occupied by not more than one family) shall have to each story above the first, two means of egress to the ground by suitable stairways, either inside or outside the building. And such stairways shall be kept free from obstruction at all times, and shall be accessible from each room in such story. The City Engineer may, however, except from this ruling fire-proof buildings, no parts of which are used for dwelling purposes. Wooden stairways shall be supported by horses not less than 2 x 12 inches, and not over eighteen inches on centers.

ELECTRIC WIRING.

62. Any electric wiring shall be in accordance with the specifications and requirements of the Southeastern Tariff Association.

REGULATIONS WITHIN FIRE LIMITS.

63. No building shall be erected within the fire limits unless the structural part of its walls be of brick, stone, iron or other incombustible material. Every interior iron column supporting masonry wall or pier must be fire-proofed by being properly encased in terra-cotta or other fire-proof material.

64. Every outside hollow frame wall and partition, every furred partition wall or outside furred wall of any building over two and one-half stories in height shall be provided with mortar, brick and mortar, or other suitable fire-stops at each story.

65. Plastering shall be carried down behind all bases.

66. Planking and sheathing of the roof of every building other than of wood, herafter erected or built, shall in no case be extended across the party wall thereof, and every roof within the fire limits shall be covered with slate, tin, copper, iron or other incombustible material.

67. The party walls in all brick buildings shall be carried up at least one foot above the roof, and shall be capped with tile or other incombustible material.

68. Every cornice within the fire limits, except on isolated buildings used as dwellings only, shall be of brick, iron or other incombustible material, and where not of solid masonry, all brick or stone walls shall be carried up behind cornices to roof covering.

SAFETY APPLIANCES.

69. In all buildings of a public character already erected, or hereafter to be built, such as hotels, churches, theatres, schoolhouses, flats, restaurants, railroad depots, public halls or similar buildings, used or intended to be used for purposes of public amusement or instruction, the halls, doors, stairways, seats and aisles shall be so arranged as to facilitate egress in case of fire or accident, and to afford the requisite and proper accommodation for the public protection in such cases. All doors of exit leading from any assembly room where crowds do congregate, shall be so hinged as to open outward from the room or rooms.

70. It shall be the duty of the owner or owners of every building used or intended to be used as a hotel, factory, theatre, tenement house, seminary, college, academy, hospital, asylum, hall or place of amusement, and of the trustee or trustees of any estate, association, society or buildings as described above, which may have its upper floor thirty feet or more above the ground, used or intended to be used for any of the purposes above mentioned, to provide and cause to be erected and fixed to said building, iron fire-escapes of a pattern which shall be approved by the City Engineer, who shall also have the right to designate the position of said fire-escapes.

PLUMBING AND DRAINAGE OF BUILDINGS.

71. No person or corporation shall carry on the business of plumbing unless licensed as a plumber. Applications for such license shall be made to Council on blanks provided by the Clerk. Such applicant shall appear before the City Engineer, who shall subject him to a rigid verbal examination as to his competency and understanding of the City Ordinances, specifications, drawings and standards, referring to the plumbing of wastes, drains, laying of sewer connections, etc., and Council shall grant license to said applicant only after a written certificate has been sent to them by the City Engineer testifying to the competency and fitness of said applicant.

72. It shall be the duty of every registered plumber to give immediate notice of any change in his place of business, for correction of the register.

73. The drainage of all buildings, public and private, and the alteration to the same, shall be executed in accordance with plans and specifications previously approved in writing by the City Engineer, who will grant a regular permit for carrying on the work, and no plumbing or house drainage shall be proceeded with unless the permit is in the hands of the men doing the work.

74. There shall be a separate plan for each building, public or private, or any addition or alteration thereof, accompanied by the specifications or descriptions for all plumbing and house drainage of said building or buildings, prescribed and furnished for this purpose, showing the location, size and kind of pipe, the material to be used, traps, closets and fixtures; the said plans to be placed on file in the office of the City Engineer; said drawings, plans, specifications and descriptions to be furnished by the architect, builder or agent, where one is employed, otherwise by the owner or reputed owner. All applications for a change in plan must be made by the owner or reputed owner, architect, builder or authorized agent.

75. It shall be the duty of the said City Engineer to give immediate attention upon receiving any notice as hereinbefore specified, and within the time therein limited, to wit: three days to report thereon, and in case that the City Engineer shall find that any of the plans, specifications, drawings, etc., connected with the work to be done, are not in conformity to this ordinance, he shall thereupon forthwith give notice in writing to the person interested, setting forth specially the grounds of objection, and upon the said parties or persons complying with the order of said City Engineer, so soon as the plans and specifications shalls be submitted, if the same be correct, to approve them in writing, and issue a permit, authorizing the construction of said house drainage.

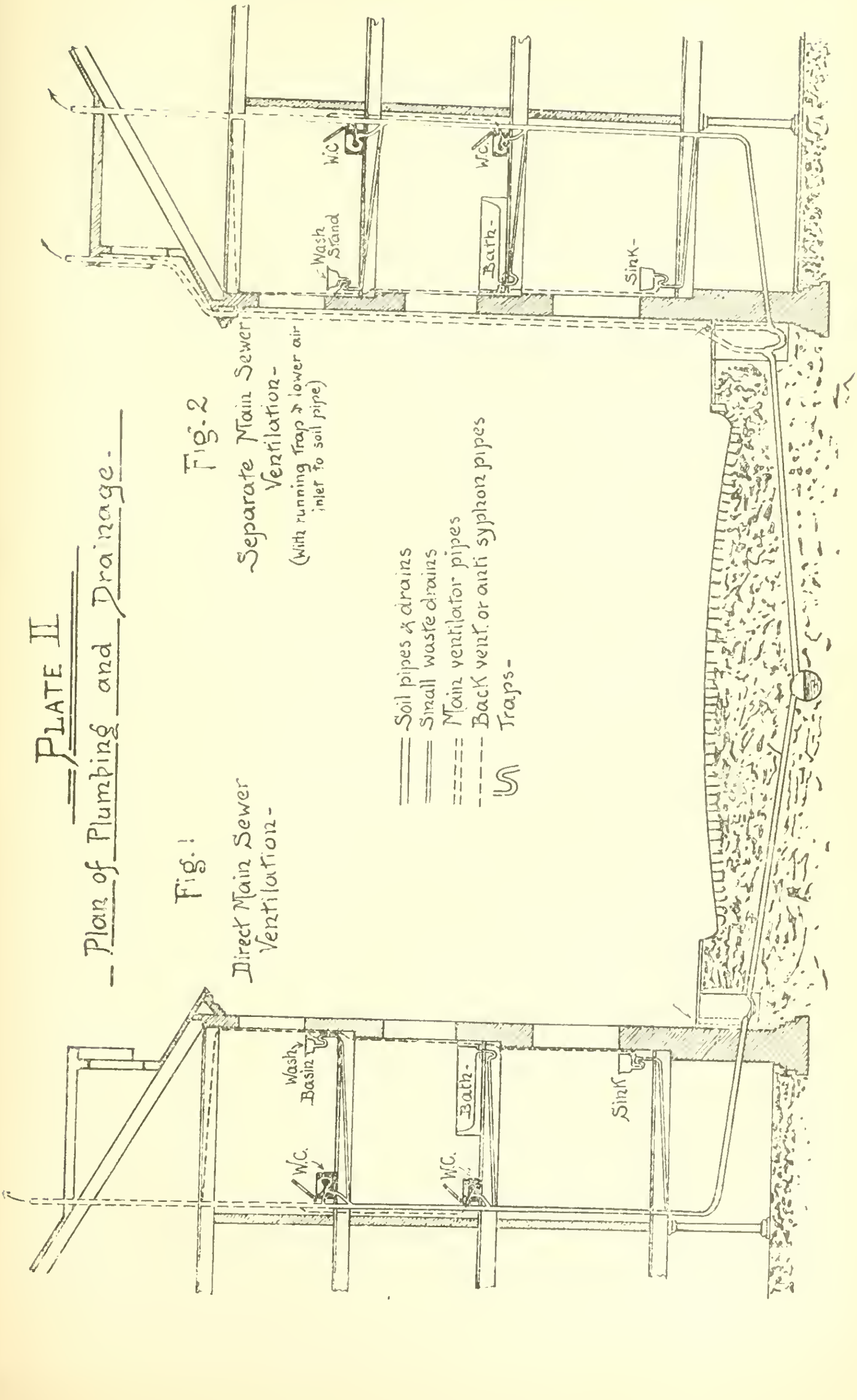
PLATE II
Plan of Plumbing and Drainage.
Fig. 1
Direct Main Sewer Ventilation.
Fig. 2
Separate Main Sewer Ventilation.
(With running trap & lower air inlet to soil pipe)
Soil pipes & drains
Small waste drains
Main ventilator pipes
Back vent. or anti syphon pipes
Traps.
Wash Basin
W.C.
Bath.
Sink
Wash Stand
W.C.
Bath.
Sink.

76. It shall be the duty of every person making or owning any drain, soil pipe, passage or connection between any sewer and any ground, building, erection or place of business, and in like manner the duty of the owner of all grounds, buildings and erections and of all parties interested therein or thereat, to cause and require that such drains, soil pipe, passage and connection shall at all times be adequate for its purpose and shall at all times allow freely to pass all that enters or should enter the same; and no change of the drainage, sewerage or the sewer connection of any house shall be permitted, unless notice thereof has been given to the City Engineer and assent thereto obtained in writing.

77. No drainage, sewerage or plumbing shall be covered or concealed in any way until after it has been examined and approved by the City Engineer or his accredited representative. Notice must be given to the City Engineer when the work is sufficiently advanced for such purpose, and it shall be the duty of said City Engineer, within three days after said notice, to inspect the same, and in case any change therein shall be found necessary, he shall direct in writing the change to be made. In no case shall any pipes, traps, or other plumbing work be permanently concealed in floors or partitions, but shall be left easy of access.

78. The main drainage of every house or building shall be separately and independently connected with the street sewer, where one is provided, and where there is no sewer in the street, and it is necessary to construct a private sewer to connect with one on an adjacent street, such plans must be used as may be approved by the City Engineer, but in no case shall a joint drain be laid in cellars, parallel with street or alley. All house drains or soil pipes laid beneath the cellar floor shall be of extra heavy cast iron pipes, with leaded and caulked joints, or of anti rust wrought iron pipe with screw joints. All other drains, soil or waste pipes, connected with the main drain, or where the main drain pipe is above the cellar floor, shall be of cast iron pipe, or of anti-rust wrought iron pipe with screw joints properly secured, and carried five feet outside of house walls, and all arrangements of soil or waste pipes shall be as direct as possible. All changes in direction on horizontal pipes shall be made with "Y" branches; all other changes shall be made with curved pipes, and where such pipes pass through foundation wall, a 2-inch clearance above and on each side of main pipe shall be provided for. All vent pipes in any building must be extended 2 feet above the roof of the main building, and above the top of any window in said roof. The diameter of any soil pipe should not be less than 4 inches.

79. All joints in iron drain pipes, soil and waste pipes, must be either screw joints tightly drawn up with red lead, or must be filled with

oakum and lead and hand-caulked so as to make them gas tight. All connections of lead with iron pipes must be made with brass sleeve or ferrules of the same size as the lead pipe, put in the hub of the branch of the iron pipe, and caulked with lead. The lead must be attached to the ferrule by a wiped or overcast joint. All connections of lead waste pipes shall be made by means of wiped joints.

80. In every water closet, urinal, sink, basin, wash tray, bath, and every tub or set of tubs, the waste pipe must be separately and effectively trapped and ventilated, unless the same shall be within 10 feet of the main soil pipe and an approved anti-syphon trap be used. Traps must be placed as near the fixtures as practicable, and in no case shall the waste from the bath tub or other fixtures be connected with a water closet trap. There shall be no traps, caps or cowls on soil or waste pipes which shall interfere with the system of ventilation.

81. All soil, waste, anti-syphoning pipes and traps, before being connected with fixtures, shall have openings stopped and be tested for inspection by filling them with water from the highest point, and allowing the water to stand in them until the inspection is completed and all leaks caulked, or by a monometer to ten pounds per square inch pressure, and all leaks stopped.

82. No pan or hopper closet shall be set up in any building. Every water closet or line of water closets, on the same floor, shall be supplied with water from a special water closet tank or cistern (the water of which is not used for any other purpose), except where the supply of water is assured, and no steam exhaust or steam from the waste pipes shall be connected with any house drain or soil pipe. No opening shall be allowed in the sewer pipe of any building for the purpose of receiving the surface drainage of the cellar, unless special permission is granted, and in accordance with the specifications of the City Engineer. No brick, sheet-metal, earthenware or chimney flue, shall be used as a sewer ventilator, or to ventilate any trap, drain, waste, or soil pipe.

83. The least inclination that can be allowed for water closet, kitchen and all other drains of not over 6 inches diameter, liable to receive solid substances, is one-half an inch in two feet; and for cellar or other drains, to receive water only, one-fourth of an inch in two feet. The depth of the crown of a drain at the curb line should be determined by a rise of one-fourth of an inch per foot from the crown of the sewer directly opposite.

84. The ends of all pipes not to be immediately connected with are to be securely stopped by brick and cement, or other water-tight and imperishable materials.

85. All pipes that must be left open to drain cellars, areas, yards or gardens must be connected with suitable catch-basins, the bottom of

which must not be less than two and one-half feet below the bottom of the outlet pipe, the size, form and construction of which are to be prescribed by the City Engineer. When meat-packing houses, slaughter-houses, lard-rendering establishments, hotels or eating-houses are connected with the sewers, the dimensions of the catch-basins, or grease-traps, which must be used, shall be required to be of size according to the circumstances of the case. When the end of the drain pipe is connected with a temporary wooden catch-basin for draining foundations during the erection of buildings, the drain layer will be held responsible for dirt and sand getting into the drain or sewer from such temporary catch-basin.

86. No private catch-basin can be built in the public street, but must be placed inside of the lot to be drained, except when the sidewalks are excavated and used as cellars.

87. The inside of every drain, after it is laid, must be left smooth and perfectly clean throughout its entire length; and to insure the same a scraper of suitable material, of the shape of the pipe and slightly less in diameter, shall be drawn through each length of the pipe after it has been laid.

88. The general plan of waste plumbing shall be in accordance with Plate II, Figures 1 or 2, as may be preferred.

89. The open ends of vent or air inlet pipes must be protected from stopping by a well-secured wire screen or perforated cap of sufficient size.

90. Drip or over-flow pipes from safes, under water closets and other fixtures, or from tanks or cisterns, shall be run to some place in open sight, and in no case shall any such pipe be connected directly with a drain pipe. No waste pipe from a refrigerator or other receptacle in which provisions are stored shall be connected with a drain or other waste pipe. Overflow pipes must in all cases be connected on the inlet side of the traps.

91. In case the general arrangement shown in Plate II, Figure 2, is followed, there must be a fresh air inlet pipe entering the drain on the house side of the running trap, of not less than four inches internal diameter, extending therefrom to the outer air, away from all windows and cold air duct of the furnace, and protected from dust or obstruction. The running traps must be so arranged that they can be readily cleaned and examined.

92. Every vent or anti-syphon pipe shall be of lead, or galvanized iron pipe with screw joints, or of cast iron pipe, tar coated, with caulked and leaded joints. These pipes, when not vertical, must always have a continuous slope, and be so arranged that water cannot collect in them.

93. Water closets must not be located in the sleeping apartment of

any building, nor in any room or apartment which has not direct communication with the external air, either by a window or air shaft having an area to the open air of at least four square feet.

PENALTY.

94. If any person shall violate this ordinance, or wilfully disobey any written order of the City Engineer as aforesaid, unless the same shall have been set aside or modified by judicial authority on appeal, or on the order or decree of the said judicial authority made on appeal as aforesaid, he shall be guilty of a misdemeanor and shall be punished therefor, and on conviction thereof shall be fined not more than one hundred dollars.

95. All ordinances or parts of ordinances in conflict herewith are hereby repealed.

96. This ordinance shall be in force from its passage.

PAVEMENTS OF CLEVELAND, OHIO, COMPARED WITH THOSE OF OTHER CITIES.

A REPORT SUBMITTED TO THE CLEVELAND CHAMBER OF COMMERCE.

By James Ritchie, Member of the Civil Engineers' Club of Cleveland.

[Read January 8, 1895.*]

To the Board of Directors of the Cleveland Chamber of Commerce—Gentlemen: I beg leave to submit to you and to the chamber a few figures collected by me in my correspondence with several of the large cities of the country relative to the cost and the methods of construction of street pavements, comparing them with the conditions which obtain in this city.

Reports have been received from Buffalo, Chicago, Milwaukee, Indianapolis and Memphis, which are complete; from St. Louis and Pittsburg, which are partial reports, while no answers have as yet been received from New York, Philadelphia, Boston, Cincinnati, Detroit and Louisville. By an examination of Poor's Manual for 1894 I have obtained figures for the last three columns in table No. 3, and these are undoubtedly correct.

Cleveland, with its mileage of streets of 544.71, has only 95.7, or about 18 per cent., paved. The average expenditure for new pavements during the ten years from 1884 to 1893, inclusive, was $323,031 per year, and in 1893 the expenditure was $860,992.

Buffalo has a total mileage of streets of 702.73, of which 302.73 miles, or about 43 per cent., are paved. The average expenditure for new pavements during the same period of ten years has been $1,088,073 per year, more than three times our average, and the expenditure in 1893 was $1,618,794, nearly twice what Cleveland expended. And yet our tax per capita is only 5 cents less than that of Buffalo, if the figures of Poor's Manual are correct.

The pavements of Cleveland consist largely of Medina stone, which is laid directly upon the ground after the same has been flooded and rolled, but in only one instance until this year has this city used a concrete foundation for its block stone pavements. In Superior Street, between the Public Square and Water Street, the new pavement was laid upon a concrete base, and is referred to in the engineer's report for

* Copy received March 6, 1895.—*Secretary, Assn. Eng. Socs.*

1893 as "the only instance in the city, excepting in the case of asphalt pavements, where a concrete base is used." This shows that we are advancing slowly to the point reached years ago by other cities of less importance than we are in other particulars.

Our brick pavements consist of a single thickness laid on sand, and I have been unable to find an instance of this kind of pavement mentioned in the reports I have received from other cities, all being in the habit of using a concrete base, except when two layers of brick are used.

In all the reports there is a universal agreement that the pavement giving the best results is the block stone laid on concrete, although asphalt and brick are mentioned as preferable for residence streets.

The reports from Buffalo are the most complete of any I have received, and show a creditable spirit of enterprise, as well as an attention to detail, which could be advantageously followed by our city. In their reports I find a description of their methods of construction of their pavements as follows:

The ground is prepared by excavating to a proper depth and form, and placing thereon a bed of concrete 6 inches in thickness, made of 1 part cement, 2 parts sand and 5 parts of 2½ inch broken stone. This is rolled with a 5-ton roller. Upon this is placed a layer of sand 2 inches thick and the block stone is laid upon the sand. The blocks are from 7 to 12 inches long, 3 to 4¾ inches wide and 6½ to 7 inches thick, laid with ½ inch joints, which are filled with pitch at 300 degrees, or with cement. The cost of this pavement complete, including excavation, curbing and concrete, is $3.50 per square yard.

The Superior Street pavement in this city cost $3.51 per square yard for the stone and foundation only, not including excavation and curbing.

The brick pavements of Buffalo cost $2.75 per square yard, and are laid upon concrete, the same as the stone, and their asphalt pavements cost $3 per square yard. Both these figures include excavation and curbing. The following table, No. 1, shows the number of miles of each kind of pavement in the cities heard from:

TABLE NO. 1.

	Block stone on sand.	Block stone on concrete.
Cleveland	77.40	.25
Buffalo	..	1.20
Chicago	..	22.60
Milwaukee	..	12.00
Indianapolis	..	..
Memphis	12.46	1.97
St. Louis	.84	45.06

	Brick on sand.	Brick on concrete.
Cleveland	15.40	. .
Buffalo	. .	3.33
Chicago	. .	1.10
Milwaukee	. .	. .
Indianapolis	. .	13 77
Memphis	. .	2.71
St. Louis	. .	. .

	Asphalt on concrete.	Wood block.	Macadam and Telford.
Cleveland	2.90	. .	. .
Buffalo	177.00	. .	2.33
Chicago	20.10	648.40	310.80
Milwaukee	2.00	44.00	
Indianapolis	20.82	2.44	2.28
Memphis	. .	1.86	13.00
St. Louis	5.27	8.35	300.00

This table shows the mileage at the close of the year 1893, and does not include any work done since that time, as far as I could learn, excepting Buffalo, which is reported to September 1, 1894.

Table No 2 gives the cost per square yard of the different kinds of pavements in the several cities heard from.

TABLE NO. 2.

	Block stone on sand.	Block stone concrete.
Cleveland	$2 70	$3 51
Buffalo	. .	3 50
Chicago	. .	3 00
Milwaukee	. .	2 80
Indianapolis	. .	. .
Memphis	1 92	4 34
St. Louis	. .	3 00

	Brick on sand.	Brick on concrete
Cleveland	$0 90	. .
Buffalo	. .	$2 75
Chicago	. .	2 10
Milwaukee	. .	. .
Indianapolis	. .	1 85
Memphis	. .	2 85
St. Louis	. .	. .

	Asphalt on concrete.	Wood block.	Macadam.
Cleveland	$2 85	. .	. .
Buffalo	3 00	. .	. .
Chicago	2 85	$0 95	$0 80
Milwaukee	2 28	1 05	. .
Indianapolis	1 55	. .	. .
Memphis	. .	1 92	1 15
St. Louis	2 75	2 75	0 75

I have also prepared a table showing the comparison between total mileage of streets and mileage of paved streets, expenditures for paving and the tax rates and bonded debt of each of the cities heard from, as follows: (Poor's Manual.)

TABLE No. 3.

	Population 1890.	Miles of Streets.	Miles Paved.
Cleveland	261,353	544 71	95 71
Buffalo	255,664	702.73	302.73
Chicago	1,099,850	2,467.00	1,003.00
Milwaukee	204,468	261.00	58.00
Indianapolis	105,436	299.60	41.00
Memphis	64,586	88.00	39.32
St. Louis	451,170	767.95	359.45
Pittsburg	238,617	220.00	175.00

	Expenditures 1893.	Annual Average.
Cleveland	$860,992	$323,031 (10 years)
Buffalo	1,618,794	1,088,078 (10 years)
Chicago	3,596,536	3,026,779 (5 years)
Milwaukee	154,000	158,900 (10 years)
Indianapolis	765,043	555,960 (3 years)
Memphis	63,688	92,000 (10 years)
Pittsburg	763,301	. . . .

	Tax Rate per $1000	Total Tax per Capita.	Bonded Debt, 1893.
Cleveland	$27.50	13.40	$7,200,128
Buffalo	15.45	13.45	12 975,829
Chicago	46.08	10.30	18,097,221
Milwaukee	21.00	13.96	5,269.000
Indianapolis	17.60	15.00	1,899,500
Memphis	17.50	10.75	3,130,000
St. Louis	13.80	11.25	21,376,021
Pittsburg	13.00	15.00	8,483,995

The total tax per capita is obtained by multiplying the tax rate by the valuation for taxes, as given by Poor's Manual, and dividing the result, thus obtained, by the population.

The report of the city director of accounts shows the following:

January 1, 1894:

Amount of General Bonded Debt		$6,129,000 00
Street Damage	$70,000 00	
Street Improvements	805,000 00	
Sewer Districts	619,000 00	
Water Works	1,775,000 00	
		3,269,000 00
Total Bonded Indebtedness		$9,398,000 00
Temporary Loans for Special Improvements		220,823 00
		$9,618,823 00

Temporary Loans Account Brooklyn village		$7,044 92
Total City Debt		$9,625,867 92
Sinking Funds—General	$1,167,289 60	
Viaduct	982,204 99	
Total		$2,149,494 59
City debt less sinking funds		$7,776,373 33
The total receipts from all sources in 1893, including cash on hand Jan. 1, were		$7,215,448 66
The total disbursements were		5,200,355 25
Leaving a balance on hand, Jan. 1, 1894, of		$2,015,093 41

The tax levy for general expense is $13.20 per $1,000, and amounts to $1,726,943.25, and of this there was received in 1893.	$1,621,967 62
Of sewer tax	120,362 52
Of special tax	550,935 45
Of liquor tax	386,440 09
Portion of 1894 taxes	200,000 00
From sale of bonds.	1,779,519 10
From sale of notes	177,888 00
From gas companies	42,113 00
From removal of night soil	31,502 72
From Cleveland City Railway (paving)	2,493 40
From sale of city farm	1,750 26
From special improvements and miscellaneous funds paid in	60,813 81
Earnings credited to different funds	931,100 94
Total receipts	$5,906,886 01
Cash on hand, Jan. 1, 1893	1,308,562 65
	$7,215,448 66

Of this money there was paid out in 1893, for street pavements, the sum of $860,992, which is about 17 per cent. of the total expenditure of $5,200,355 previously noted.

The ordinary expenses of the city government for 1893 were $1,-798,556.29, which is divided as follows:

Current expenses,		Mayor	$38,568 63
"	"	Public Works	146,597 37
"	"	Auditor	20,843 68
"	"	Law	13,873 24
"	"	Charities and Correction	1,253 92
"	"	Legislative	34,658 32
"	"	Treasurer	8,574 92
"	"	Elections	14,458 52
"	"	Judicial	31,761 45
Total general fund			$310,590 05

Carried over	$310,590 05
Bridge fund	86,609 82
Street fund	139,033 56
Water Works	185,082 70
Parks	30,850 04
Police	325.771 16
Police court	23,676 94
Markets	24,188 76
Sanitary	35,950 99
Cemetery	26,344 12
House of Correction	111,163 07
Infirmary	128,133 58
Fire department	346,403 38
Dredging fund	24,758 12
	$1,798,556 29

These figures and others in the auditor's report show that the ordinary expenses of the city government are about 35 per cent. of the total expenditures. This does not include new and permanent improvements, but is supposed to include salaries, office expenses and the general expenses incident to maintenance and ordinary repairs.

The special improvements and the permanent improvements in 1893 cost $1,737,784.35, or about $60,000 less than the charge for maintenance and general expenses. The interest paid on bonds and notes was about $954,000.

These figures show, in relation to the subject in hand, that while our city has expended over $5,000,000 in 1893, only about one-third has been expended for permanent improvements and about one-half of that amount has been for new pavements. And, while these are called permanent improvements, only one section of the stone pavement and none of the brick pavements laid have been done in what is usually considered a permanent manner. While it is undoubtedly true that our pavements compare favorably in some respects with pavements of other cities, I think great improvements could be made in the methods used in the work of construction. There is not enough attention paid to obtaining the best results. Permanence in construction means economy in repairs, and every means should be taken to secure good foundations and proper materials. The appointment of inspectors should be regulated by the ability of the men and their knowledge of the character of the work and methods to be used, and political influence should be utterly disregarded. The federal plan of government enables the officials to disregard the matter of politics when they desire to do so, and our citizens should see that the officials are men who will throw aside personal and political feelings and only work for the general good.

The methods employed in the maintenance of our streets are being

improved. Efforts are being made to change the character of our street department from its condition of a "rest for the infirm," as the report of the department of public works states, and the result has been to place it upon a business-like basis. Certain reforms have been made and more will come. Our streets, however, are at no time clean, and the mud upon our pavements should be kept down. Yet the principal reason for their being in such a condition is the fact that from all sides there are dirt roads entering the city, intersecting our paved streets and depositing, through the medium of hoofs and wheels, their mud and dirt upon our pavements. Also, as shown in the tables within, we have only 18 per cent. of our streets paved, and the other 82 per cent. are assisting in the defilement of our pavements. In 1893 the street department expended over $138,000 in material and labor for repairs to street pavements, sewers, drains, catch-basins, and cleaning the streets, sewers, and catch-basins. The item for cleaning paved streets amounts to about $30,000 for 1893, which is about $300 per mile for the year. The cleaning, rounding and filling of unpaved streets costs the city over $52,000, and this appears to be a waste of money. After the first heavy storm the surface of these streets was deposited upon the adjoining pavements. Three hundred dollars per mile per year for cleaning the paved streets does not seem like a waste of money, but when a street becomes immediately in the same or worse condition, we feel impressed by the uselessness of the work. There is a remedy which our city must apply, and that is to proceed at once to make such permanent improvements in the way of draining and paving that before long our whole city will be in such a condition that dirt upon our pavements will be unknown. Let us see what such a move involves. Until a street is to be paved the old sewers are usually considered sufficient; consequently, when new pavements are put in, a new sewer has usually to be built. Last year (1893) there were built 13.986 miles of sewers of various kinds, at a total cost of $317,272.40, or an average cost per mile of about $22,700. There were paved 18.67 miles of streets, at an average cost of about $46,600. The average cost, therefore, of draining and paving the streets of this city is $69,300, or say $70,000 per mile. There are about 400 miles of unpaved streets, which, if paved and improved, would give this city an advantage over many others in appearance and in healthfulness.

Four hundred miles at $70,000 per mile would be $28,000,000. If we should keep up our present rate we should accomplish this result in about twenty-five years, if it were not for the fact that a part of our work each year is repaving. There is where we lose money by our economy in first cost and our old-fashioned methods. It costs Buffalo 80 cents more per square yard for stone pavement laid on concrete, than it costs us for stone pavement on sand; that is 30 per cent. There

can be no doubt in the mind of any one as to the superior advantage of a pavement with a foundation over one without. These advantages are as follows:

The concrete is calculated to so distribute the loads and weights of the pavement as to prevent unequal settlement, and is practically the same thing as a single band of solid rock upon which to support the surface. The two inches of sand act as a leveler and cushion, preventing the inequalities in the upper surface of the concrete from being felt in laying the stone, and preventing the blows from heavy traffic of the street from being too suddenly communicated to the concrete. The pitch, which fills the joints, prevents water from penetrating to the foundation, where it would freeze and heave the stone irregularly and at the same time damage the foundation. With this kind of pavement it is essential that the engineer shall have sufficient foresight to enable him to put in absolutely all the pipes and curb connections needed, for it is practically impossible to replace a pavement of this sort and make it as good as at first. The wearing surface of this pavement will last better than our present ones, will retain its form and evenness, and, when it requires changing, can be taken up without disturbing the concrete, and new pavement can be laid at a less expense than it costs us to repave. Adding to our estimate of $28,000,000 the extra cost for concrete foundations, we have about $35,000,000 as the estimated cost of these improvements. Our valuation for taxes is about $126,000,000, and the expenditure of $35,000,000, which is over one-fourth of our valuation, looks like a preposterous idea. But what would the result be? Experience in other cities has shown that the value of the abutting property is increased to a great extent by such improvements, and I have no hesitation in saying that an expenditure of $35,000,000 in our streets and sewers would so increase our valuation that the advantage to our city would be enormous.

In cities with good pavements the rates of fire insurance are less than in those having inferior streets. Again, we would gain from pavements.

Cleanliness is next to godliness, and, as we can never hope for the latter in a large city, let us secure the former and conduce to the public health by keeping our streets clean and our sewers in order.

Speaking of sewers, I hope the time will come before long when the Cuyahoga River shall be cleaned and purified. There are ways to do this, and among other means I would suggest that instead of emptying our sewers into the river, we construct an intercepting sewer on each side of the river into which all sewers must empty, and, connecting these two into a main sewer along the lake front, let the latter empty into the lake as far east as possible. This is merely a suggestion, and

the details of it, when worked out, might show obstacles and objections not easy to overcome except at great expense and by the use of machinery and pumps. But it seems to me that unless something is done very soon the health of our people, and thereby their usefulness, will be destroyed and our city will become a nuisance to itself and to the world.

What we need is a spirit of push, energy and ambition, together with the pride in ourselves and our city which conduces to growth and improvement. There has been too much holding back and objecting when public improvements are proposed; too many citizens who do not see that the interest of the whole city is their interest, and the improvement of a part of the city indirectly helps the whole.

DISCUSSION.

Mr. M. E. Rawson.—For a great many years I have been connected with work on the city pavements, and I have yet to learn just how to pave and with what material. Our pavements compare favorably with those of other cities. I think there are some pavements down to-day that were laid in 1858, 1859 and 1860. They are therefore 35 years old. What more could six inches of concrete foundation have done? If we had foundations of clay or drift as they have in Chicago, we should have done differently from what we have done. Perhaps we have made a mistake in not putting in foundations earlier; but it does not follow that because they do it in Chicago or in Buffalo that, therefore, it should be done in Cleveland; for we have very different soil. We are continually digging trenches 6, 10 or 20 feet deep. If these give way neither six nor twelve inches of concrete will hold the pavement after the foundation has given way under it. Trenches are liable to go down, and will go down in spite of all the care you can take. I believe the time is coming when we should put down more concrete foundations of broken stone as the traffic of the city increases. We must provide artificial drainage and carry the water away from the foundations. All of our block stone, and, in recent years, all of our common stone pavements, are laid with cement filling which is impervious to water, and the surface water is thus shut off. In some places, where they are putting in concrete foundations, they are simply filling in the pavement with sand, which allows the surface water to reach the foundations.

Mr. Ritchie has said that before the engineer commences to pave a street, he should have such a knowledge of it that he can put in every pipe and every connection which will be needed in the future. No man

has ever been found that can do that. You cannot tell where six-inch or four-inch water connection, or six or nine-inch sewer connection will be wanted. These things cannot all be anticipated. The gas companies and water works are continually enlarging their pipes. A sewer built years ago and sufficient for that time, is found inadequate when larger blocks with deeper basements are built. The house which a man builds when he is worth four thousand dollars is different from that which he builds when he is worth ten thousand, and different again from the one he builds when he is worth fifty thousand. It is so with towns of ten, fifty and one hundred thousand inhabitants.

In Buffalo, nine-tenths of all the pavements are asphalt; they are beautiful to look at, and, when made as well as they can be made, are very satisfactory; but I have seen some pavements there with concrete foundations that do not compare with our pavement on Superior Street, laid only on earth foundations. It does not follow that because Case Block was built upon a pile foundation, that therefore the City Hall on the opposite corner should have had that kind of a foundation. When they built the City Hall, the ground water had been drained nine or ten feet deep and the conditions were entirely changed. And so a concrete foundation for a pavement is not better if it does not serve a better purpose. It does not follow that six inches of concrete would be better because it costs more. A city engineer cannot always do the thing that he would. Every man here is a king, he owns his property and a right to the street in front of him, and he has his say. The City Council is made up of individuals who are susceptible to his influence, and no engineer can crowd his own ideas through the Board of Control or City Council. I believe we ought to have better pavements, and I think we should get into our specifications something that will make them better. I believe Medina stone is the best material we have in this section for streets of heavy traffic. Pavements of this material do not become brittle or slippery. They do not make as smooth a pavement as brick, or as easy a pavement as ashphalt. Asphalt, when it is as good as it can be made, makes a beautiful pavement; but laying an asphalt pavement is a good deal like making bread. It may be successful to-day, and to-morrow it may not be so successful. The failure may not be the fault of the contractor. In one street where a portion of the pavement was taken up after it had been down but a short time, the contractor told me that he thought the material first class, but that it must have been chilled in transit, as it was late in the Fall when laid. You cannot always select your contractor, where the cheapest contractors get the work. I wish someone would tell us a better way.

Mr. John L. Culley.—I quite agree with Mr. Rawson in what he has

to say relative to the use of concrete base under sheet pavements. Concrete base for pavements has become a fad with engineers all over the country, *per se*. It must be used without regard to local requirements. In many of our smaller cities this has been a fruitful source of municipal extravagance and of burdensome taxation. As a general rule it may be stated that for corporations of less than 10,000 inhabitants there is no traffic to warrant the use of concrete base under pavements. In determining the question whether such base is a necessity, the character of the soil and of the traffic should be the directrices. Throughout the resident portion of Cleveland there is no necessity for concrete base over our sandy, gravely soils, nor is there over clay soils or for drift if the subgrade is properly drained and prepared. Some four or five years since I had charge of the brick paving of the west end of Detroit Street, then in the corporation of West Cleveland, on the worst kind of soils, composed of clay, drift and "wash stones." The sub-grade was excavated to crown 12 inches between the bottom of the pavers when in place. These 12 inches were then filled with a gravel of good quality, thoroughly puddled and rolled. Ordinary 4-inch field tile were placed under each curb. This pavement does not to-day show any signs of wear or of settlement. Undoubtedly, such a pavement, in business localities of concentrated traffic, would not be able to stand up, and would need a stronger base.

Engineers, accustomed to concrete or other hard base under pavement for residence streets, are surprised to find us using earth under ours. They are also surprised to see them stand up here. The reason for this lies in the better preparation of the base, and in the superior construction.

A weak point in pavement construction in this city is the method of refilling with earth and water, sewer and gas pipe trenches, particularly the sewer trenches. They are refilled by (so-called) puddling in the earth.

Specifications require each 18-inch layer of earth to be flushed or puddled with water. Practically the trenches are filled up at once within 18 inches of grade before any puddling is done. Naturally, water turned into a trench thus prepared quickly finds its way to the sewer. The earth is not compacted, and a depression is soon developed in the pavement over the sewer. All of this may be avoided by tamping in the whole trench from sewer to street grade. One rammer to two shovels will answer. This involves no increase of cost over puddling. The expense of carting away the surplus earth in sewer construction would more than offset that of ramming it back into the trench. All this work, of course, should be done under the sewer contract.

Col. J. A. Smith.—Of course, everyone knows that one of the greatest dangers to our pavements is due to the settlement that comes from the earth becoming more compacted in these trenches that have

been dug. I have noticed that in almost all cases they return the earth by the process of puddling; sometimes by the trenches being filled, and sometimes by poling it in when the trenches are nearly full. There seems to be an idea that by getting water into the earth they get more of the earth back than otherwise. That may be true with certain limitations of labor saving. There may be more earth settled back when we puddle it in than when it is simply shoveled without ramming. I think this idea was derived from the fact that when we puddle a dam it is less likely to be permeated by the water. But the principles involved in the two cases are different. Many years ago my old friend, W. J. McAlpine, the former president of the American Society of Civil Engineers, in conversing with me, dropped this remark: "Water abhors a vacuum;" and in the subsequent discussion this remark was considerably elaborated. A particle of water, passing through a puddled dam, finds no cracks or seams, but must turn constantly at every moment of its passage, so that ultimately the friction and the other resistances it meets tire it out and stop the leakage. That same principle is found in a thousand things we meet in hydraulic engineering. But it does not follow that the quantity of material in a dam is what causes its imperviousness. Because the dam does not leak when it is puddled, it does not follow that there is more material in it, but merely that the material is so disseminated that the water cannot find passage. If the earth were replaced in thin layers and thoroughly rammed, I think the subsequent trouble would be reduced to a minimum. I do not know whether it could be prevented entirely. I believe the use of water, instead of being a benefit, is a positive injury.

Mr. H. M. Claflen.—It is now thirty years since I commenced to do paving, and during that time I have laid, in eighteen of the larger towns, from Rochester to Chicago, every kind of pavement I know anything about. No man has ever yet laid a perfect pavement. The Appian Way comes as near to it as anything, but the construction there used is among the lost arts. The subject of pavements is of more importance to a city and to the people of this country than they appreciate. A well-paved town and clean streets bespeak the character of the population of that town. I do not think the engineers are always responsible for poor pavements, any more than architects are always responsible for poor buildings. Suppose an architect is requested to make plans for a block. He submits them with estimate, and the proprietor says "No, can't stand it; cut that in two." What is the result? You see it all over Cleveland, and you cannot blame the architect. It is so with engineers. If you had assessed upon property owners fifteen years ago a tax that would permit the laying of a first-class pavement, I have no doubt there would have been a "kick." This

city has been slow to progress in that matter. Sixteen years ago I laid the first block pavement that was laid here, and I could not get any pay for it at all. I am not paid for it to-day. Why? They thought I was crazy to lay such a nice piece of pavement, and they would not pay for it even as the price of a common pavement. It is in existence to-day, and people saw in due time the result and began to want that kind of pavement, and I have laid many miles here, as well as in other cities. As a general principal of engineering, the man who puts in scant material, and the man who puts in more than is necessary, are both guilty of poor engineering.

In reference to foundations of pavements, the success of the block-stone pavement which I was the first to lay in this country, and which was laid on a sand foundation, filling the interstices with cement which keeps out the water and preserves the foundation, has been to my mind a matter of wonder. There are pavements of this kind which I laid fifteen years ago, and which are in perfect condition to-day without any settling. But, if it were left to me, I think I should put a foundation under all pavements, both brick and stone; but I would not use concrete. I do not think it is necessary. In 1872, High Street, in Columbus, was paved with asphalt. Some ten years later the asphalt was taken out and the street was repaved with block stone. In doing that work we had the old concrete under the asphalt to dispose of in some way. It was picked up, leveled off and rolled with a heavy steam roller. On top of that was put a cushion-coat of sand, and in that was set the block stone, the interstices being filled with cement, and it is there to-day in perfect shape. Third Street was, soon afterward, paved with block stone, and the same specifications were adopted, and the street was paved in the same way. It is a perfect street to-day. Nearly all the paved streets in Columbus have been treated in the same way. The advantages of that treatment are, (*a*) saving in cost; (*b*) a street can be paved with less inconvenience without discommoding the business of the street.

Summit Street, in Toledo, is another instance of paving on a sand foundation. I paved that street with block stone about twelve years ago. Summit Street is on a bed of clay, and when it was paved a water-pipe was put in on one side, and a sewer on the other side, the railroad tracks were relaid, and water and gas connections were put in. It looked as though the rabbits had occupied it. However, we replaced this material, ramming it thoroughly. Puddling was impracticable. We put on twelve inches of good lake sand, and paved the street in that, and it is as pretty a piece of pavement as there is in that or any other town. It has not settled. But my suggested broken stone foundation makes a sure thing in any doubtful case, and is not very expensive.

The Chair.—During my recent trip abroad I often heard Ameri-

cans speak of the good pavements of London and Paris, and of the poor pavements in our large American cities. I believe our engineers understand the methods of laying pavements as well as those abroad, but in Europe they take a great deal more pains in putting them down and better care of them after they are down. In Berlin I saw them laying stone pavements of granite blocks perhaps an inch larger each way than those used by us. They first prepared the roadway with a heavy roller, and then put on the small broken stones. The stones were not tumbled in by the cart-load and then leveled off, but men on their hands and knees were carefully placing each piece in its proper place. They then put two or three inches of gravel on top, over which the block stones were laid. On the end of every stone was a large figure showing that it had been inspected as to quality, size and shape. They all seemed to be perfect stones, but there must have been considerable difference in them, for they were figured from one to four. The gravel for filling the spaces between the blocks was not dumped on top and washed in with a hose, as we have often seen it done here, but carefully tamped in. After the proper amount of gravel was put in, the remaining spaces were filled with cement. The work throughout seemed to be done with the greatest care, so that if there was to be any settling at all it should take place uniformly over the whole street, and not in spots. In London I saw a pavement being put down consisting of concrete about six inches deep, covered with a cushion of gravel upon which the granite blocks were laid.

Wood-block pavements, laid upon concrete, are extensively used throughout London and upon many of the streets having the heaviest traffic. Asphalt also is largely used, the same as in Paris. In these cities special care is taken to keep the streets in good repair. On the Strand I noticed they were taking up a pavement of wood blocks that had become somewhat worn and irregular, but which we would call in fair condition, and would probably have left it for several years. The wood blocks are quickly replaced by new ones, much of the work being done in the night. The splendid condition of the streets, together with the rubber tires, which are now universally used upon the wheels of the cabs, make driving about London very pleasant.

Mr. Claflen.—Of course, London is ahead of us about a thousand years in experience, but we have made great progress in this country, and with cheap money now attainable we can make further progress. When I laid the first pavement here on Superior Street, in 1868, I had to take 8 per cent. bonds in payment. I could not sell them here. I went to Boston and there sold, for 72½ cents on the dollar, the first chartered city bonds ever issued for paving. You can figure from that and see what it cost the people of this town to furnish money for paving at

that time, and how hard it was to introduce a first-class permanent pavement, which must be expensive at the first.

Mr. A. H. Porter.—I wish to say just a word in approval of the course that has been pursued by our engineers in the matter of paving here in Cleveland, up to the present time. We have read and heard so much about our poor pavements, that without a little reflection on our part, we are likely to think that a large portion of the money invested in our pavements has been actually squandered, while the facts are that the money has, in the main, been exceedingly well and judiciously expended, and we have to-day pavements that will compare favorably with those of any other city, of equal size, in the country.

I believe in doing all work, public and private, in the best manner possible, for the purpose in view; but to do this often requires the most careful study of the problem to be solved. It requires no more talent or skill to design a work which is too good and expensive, than it does to design one that is inferior and inadequate to the purpose for which it was constructed. Engineers have committed the first mistake far oftener than they have the second, and all of our cities and the country are full of works of this kind, but they are less known than the comparatively few failures that have been recorded and widely published. Extravagance has been far more productive of bankruptcy than a too sparing use of proper materials.

Cleveland is now paving large areas every year, and I am pleased to state that all that is laid under the specifications and supervision of our city engineer, is admirably adapted to the purpose for which it is to be used. The worst specimens that we have, those which have called forth a large part of the unfavorable comments we have heard, are those which have not been thus put down under the supervision of the city. There is no doubt that the most substantial pavement will last longest under the most severe traffic; neither is there any doubt that a cheaper pavement would last just as long on some other street with light traffic.

Cleveland is certainly well favored in one respect, and that is that the foundation of our pavements is the sand which underlies all of our streets, and which is easily drained as soon as a sewer is built This can be wet and rolled so solidly that in walking across it not a footprint will be seen. It furnishes an excellent foundation for a cheap pavement on many of our side streets where traffic is, and probably always will be, light. I live on a street that has been paved with brick for three and a half years, and not a brick has been removed for any cause whatever, and there is not a broken brick on the street, nor a place that shows the slightest signs of settlement, even after a rain. This pavement was laid under the most rigid inspection, directly upon the sand of the street,

after it had been properly graded and rolled, and I believe that a better, cheaper and more satisfactory pavement is not to be had. I do not pretend that this would be suitable for all streets, but there are large numbers of streets in all of our cities where it would prove the ideal pavement. It can be laid and paid for in innumerable instances where some of the other kinds would almost cause practical confiscation of the poor man's property on the street. I also think that traffic should be so regulated by law as not to allow the destruction of our lighter pavements by a small amount of exceedingly heavy hauling, which can just as well take some other route where it will cause no damage.

President Swasey.—Reference having been made to the Appian Way, I would like to say a few words in regard to that "Queen of Roads," which I visited a few months ago. One of the most interesting sights to the traveler in Rome is the ride of six or seven miles over that highway, built 300 years B. C. The road is composed of smooth flat stones about 2 feet across, of irregular shape, well fitted together. I measured the width of the roadway at several points about a mile apart, and found it to be 13 feet 9 inches from curb to curb, with scarcely any variation. For much of the way the original stones are left bare, showing their smooth, polished surfaces which almost glisten in the sunlight. These stones are so hard that they show but little wear from the wheels which have been passing over them for so many hundred years. The road extends as far as the eye can reach over the Roman Campagna toward Naples until it vanishes into a faint line over the mountains, and it is as true and straight as the engineer of to-day could lay it out with his most improved instruments.

As to the construction of the Appian Way being a lost art, we should consider where it is located and the conditions under which it was built. In the first place, the climate is all that could be desired. There is scarcely any frost or snow, and the atmosphere seems to preserve the building materials instead of destroying them. Structures which have stood in Rome for 2000 years, and will, no doubt, stand as long again, would, if in this country, commence to decay in a very few years. The natural foundation upon which the road is built could not be better, for it is the same volcanic tufa which was used in the Roman cement, and in which the Catacombs, beside the Appian Way, are excavated. These underground galleries, some of them with vertical sides 8 feet or 10 feet high, have stood, without caving in, ever since the second century; and no wonder that in such a climate and with such a foundation the hard flat stones of the Appian Way have remained just as they were laid 2000 years ago. I believe that if our Engineers were given similar conditions and materials, they could construct a road equally good.

CARBON DIOXIDE FOR REFRIGERATION AND FOR EXTINGUISHING FIRES.

EXTRACTS FROM A PAPER BY E. F. OSBORNE, MEMBER OF THE WESTERN SOCIETY OF ENGINEERS.

[Read November 7, 1894.*]

ATTEMPTS have been made to distribute artificial refrigeration in a limited territory by the use of anhydrous ammonia. The cost of this material necessitates its return to the central station, involving, in the construction of a plant, not only the pipe for its distribution, but pipes and fittings larger and several times more expensive than the distributing pipes, for its return; and in practice it has been found necessary to employ three pipes, with the attendant complication and expense, both in construction and maintenance. The meter measurement to the consumer is not satisfactorily operative, and automatic regulation is impracticable, if not impossible; still, the demand is so great for even this crude service, and it is so much superior to the use of ice, that consumers cheerfully pay a price sufficient to make a small and expensive plant of this kind commercially remunerative. Furnishing a product without measurement is commercially possible only on a limited scale.

I do not wish to detract one iota from the credit that is due to those who have perfected the ammonia refrigerating machine, but the causes that have almost invariably effected a failure in district steam heating plants operate to produce a failure in district refrigeration by the ammonia process, to wit: Too great complication and expensive construction, no practical system of meterage or means of regulating the effect produced, together with excessive expense for maintenance and inspection.

Pipe-line refrigeration has come to stay, and will displace ice for nearly all purposes for which the same is now used; and some system other than that in which ammonia is used must and will be used in all places where refrigerating effects are to be produced on a large scale, and divided among many small consumers, in the same way that natural and fuel gas has replaced steam for heating purposes under similar conditions. Carbon dioxide is the substance to be employed for the following reasons, namely:

Less cost of production, less complication and therefore less expensive construction; less cost of maintenance and less need of inspection,

* Manuscript received March 18, 1895.—*Secretary, Assn. Eng. Socs.*

together with accurate measurement of product and easy regulation of effect, with incidental uses not obtainable with ammonia.

The following may be called a commercial law :

No commercial enterprise on an extensive scale can attain and maintain enduring success that must recover its product; that has no substantially accurate and readily comprehended means of measurement upon which to base charges for product furnished, or that cannot regulate, either automatically or readily by the assistance of the consumer, the effect produced by the product furnished.

Carbon dioxide possesses the physical properties and can be produced, delivered and furnished to small consumers under such conditions as to force its adoption for the many purposes for which it is so pre-eminently adapted. It can be produced so cheaply that its recovery would materially increase the cost of its production. It is comparatively a harmless gas, as it is a necessary constituent of many articles of food and drink. It is the best available refrigerant known to science, being capable of producing a temperature in a few minutes even more than 100 degrees below zero Fahr. It is, therefore, useful in many chemical processes where ammonia could not be employed. It is odorless, and neither inflammable, corrosive nor explosive. It is the best preservative of furs and woolen goods known, keeping them from the ravages of insects and worms without impregnating them with any odor.

The loss occasioned by the average fire is due more to the water than to the fire. In many cases the amount of goods actually consumed or damaged by the fire and smoke is less than one-tenth of the damage done by the water used to extinguish the fire.

The well-known properties of carbon dioxide to extinguish fires have been used in portable fire extinguishers and chemical engines. One of the advantages of carbon dioxide for extinguishing fires is, that the heat produced by the fire assists in its own extinction by inducing a current of mixed air and carbon dioxide to flow to the point of combustion, and thereby extinguishing or wiping out the fire just as water would be wiped off from either a vertical or horizontal surface with a dry sponge or rag drawn over it.

I have devised a system and devices by which carbon dioxide may be produced in a liquid form on a large scale, at a comparatively insignificant cost; and have devised processes, methods and apparatus for its utilization. The devices are simple in construction, readily understood by the average mechanic; they are easily constructed and put in operation and can be tested at any time without danger to the operator.

It requires but a very small amount of gaseous dioxide to extinguish a fire in its incipient stages, from 4 to 10 per cent. is ample. As the gas comes out it falls to the floor, mixing with the air as it goes. The heat

caused by the fire induces a flow of the mixed air and gas to the exact place where the combustion is going on, and immediately extinguishes it. As soon as the fire is extinguished, the temperature of the air at the ceiling is reduced, the thermostat ceases to operate, the automatic valve closes, and the apartment is in the same condition as it was before the fire.

This gas can be adapted for use in refrigerator cars. It will also give preservation with a dry atmosphere, with but little refrigerative effect, or a freezing temperature to keep frozen goods.

The system consists of a central station provided with one or more gas producers, calcining retorts, distilling apparatus, boilers, engines, pumps, compressors and incidental apparatus. The raw materials required are soft coal and limestone. The products are carbon dioxide, commercial lime, carbonate of ammonia and coal tar.

The coal is supplied to retorts, and subjected to destructive distillation, in nearly the same manner as in ordinary gas works, the tar and ammoniacal liquor being separated, the former being sold in that state and the latter distilled and converted into carbonate of ammonia, packed and sold. The coke is converted into a semi-water gas, which is used to calcine the limestone. The lime produced is of the best quality and is sold on the open market either in bulk or by the barrel. The dioxide is purified, cooled, compressed and liquefied in the same way as is done in ordinary manufacturies where this substance is produced for commercial purposes. The liquid dioxide then passes by its own pressure into the main distributing pipes in the street. At the curbstone is a service cock; just inside of the consumer's premises is an automatic valve, which cuts off the supply in case of a break or careless management of the apparatus on the consumer's premises; if the break is permanent, or anything has happened equal to a rupture of the service pipe, the supply remains substantially shut off. When the damage is repaired and normal conditions established the supply is automatically turned on. From this valve the dioxide passes to a meter, thence to the automatic regulating valve in the refrigerator, which is set to maintain any temperature desired, from which valve the dioxide is conducted into the cooling chamber or coil located in the space to be cooled. Thereafter the dioxide in gaseous form may be used to charge drinking water, ale, beer or wine, and for forcing these or other liquids from a lower to a higher level, as from the basement of stores and restaurants to any floor above; or the gas can be used for the preservation of nearly all kinds of food products, where a low temperature is not necessary, especially for fruits, vegetables and meats. It can also be used for small powers, and the heat that is extracted from the substances cooled goes a long way towards furnishing the motive power required in connection therewith.

Briefly, the services above referred to are to be furnished from a central station, somewhat similar to a gas or water works plant, and the carbon dioxide, after its production, delivered into flasks or cylinders for use on board cars, ships, or at other places not directly connected with the central station. Or, the dioxide is delivered into a ramification of pipes leading to the premises of the various consumers where it is metered, automatically regulated, and the resulting gas allowed to go to waste.

One ton of good soft coal and 3½ tons of limestone will produce rather more than 3,500 pounds of lime, 3,000 pounds of carbon dioxide, 6 to 7 gallons of coal tar and 40 to 50 pounds of carbonate of ammonia.

RAILROAD SIGNALING.

By Charles S. Churchill, Member of the Association of Engineers of Virginia.

[Read January 17, 1894.*]

In the most primitive method of operating a railroad all trains are scheduled and have stated meeting points. Each meeting point must be made within a given time limit. This plan primarily requires no signals; in other words, the absence of a danger signal means safety. Carrying out this general idea, switch stands are sometimes made with but one target; the edge of that target faces the train when the main line is clear, and the whole target shows at danger when the main track is not clear.

As the business on a road increases, this primitive method requires extension and change. At given points along the road, at distances as nearly uniform as possible, telegraph operators are stationed, who, acting under a dispatcher, give special train orders, using a danger flag or its equivalent when orders are at hand.

In the next advanced step, all train-order stations are equipped with fixed signals, each conveying one of the three ideas—danger, caution and safety—and controlled by the operator under the direction of a train dispatcher. The absence of a signal still means safety, and a fixed time interval is required between all trains. French roads are mostly operated on this plan, and it is said that, notwithstanding its defects, good results are secured, the system being carefully worked out. Many miles of railroad in this country are still operated on this plan.

Under the next more advanced plan the movements of trains are governed by telegraphic orders in addition to time tables. This requires a number of offices along the line of the road, with an operator on duty in each, and a fixed signal under the control of the operator, directed by the train dispatcher. Each signal shall show danger except when changed to safety to allow a train to pass, after getting orders, or after ascertaining that there are no orders. In this system the absence of a signal means danger, and requires a stop, with the protection of the trains under the rules. The time interval is in force, since there are often more than one train between two train-order offices at the same time. Very many miles of road in this country are operated under this system. The distance apart of the train-order offices is determined by the amount of traffic to be handled.

* Manuscript received March 11, 1895.—*Secretary, Assn. Eng. Socs.*

A still further improvement, both in safety and in rapidity of train movements, is secured by dividing the road into blocks; *i. e.*, approximately regular spaces, and placing at each end of each block an operator controlling the signals under the direction of the train dispatcher. In this case the operator may show three forms of signals: first, a signal signifying safety and giving the information that the track is clear, subject to the regular schedule; second, a cautionary signal, showing that a train has preceded at a given number of minutes constituting the time interval; or, third, a danger signal, showing that the track is occupied or requiring a train to stop for orders. This system, in its most complete form, is known as the "Block System," and, in its most complete manner of operation, is known as the "Absolute Block." The time interval is no longer used, and but one train is allowed in a block at the same time.

In operating the block system, either no signals at all are required, as in the case of the staff system; or, if operated by signals, the road must be very completely equipped with them. In the staff system, the engineer of a train receives at the entrance of a block a staff, which is equivalent to an absolute train order over that block and gives him right of track until he delivers it to the operator at the other end of the block.

In addition to the blocking of the road for the operation of trains, grade crossings, junction points, yards, etc., on a busy road, require their switches to be interlocked for safety and thrown by one operator from a tower. This necessitates a complete system of signals for the government of trains at such points, and, of course, this system must be in harmony with whatever form of signaling is adopted along the main line of the road.

In the following I will attempt to describe some of the systems employed, and the methods of signaling; and first I quote some definitions expressing the views of the American Railway Association on block signals, but make note that items 7 and 8 below are omitted from the definitions last issued.

(1) *Block.*—A length of track of defined limits, the use of which, by trains, is controlled by fixed signals prescribed and established for that purpose.

(2) *Block Signals.*—Fixed signals prescribed and established for the purpose of controlling the use of a block.

(3) *Home Block Signal.*—A fixed signal at the entrance of a block, to control trains on entering and using said blocks.

(4) *Distant Block Signal.*—A fixed signal of distinctive character used in connection with a home block signal to regulate the approach thereto.

(5) *Advance Block Signal.*—An auxiliary fixed signal placed in advance of a home block signal and worked in connection therewith.

(6) *Block Signal System.*—A series of consecutive blocks controlled by block signals.

(7) *The Absolute Operation* of a block signal system permits but one train at a time to occupy the block.

(8) *The Permissive Operation* of a block signal system permits under certain regulations, more than one train at a time to occupy a block.

(9) *A Telegraphic Block Signal system* is one which is operated manually, as directed by telegraph.

(10) *A Controlled Manual Block Signal system* is one which is operated manually, but which, by its construction, prevents the display of a "clear signal" while the block is occupied by a train.

(11) *An Automatic Block Signal system* is one which is self-operative, whether by mechanical, electrical, pneumatic or other device.

A block signal may or may not be of the same form as those used for interlocking or for train orders. The practice of roads in this country and in different countries varies greatly in this respect.

According to the practice in this country, the position of signals is most generally to the right of or directly over the track governed. This practice is not uniformly followed in Europe, however. It is a fundamental law of signaling, that, when out of order, signals shall go to the danger position, whatever that may be; that is, they should go to danger automatically.

The meaning of a signal may be conveyed either by color or by position. In this country the general practice requires that the meaning is to be conveyed by a combination of color and position. The three plainest colors are red, white and green; hence, these colors have been adopted for railroad signaling. In this country white is generally used to signify safety; green is used to signify caution, and is, therefore, used for distant signals, while red is used to signify danger and an order to stop. From the fact that when the glass of a night signal is broken, a white light would appear, it has been thought undesirable to use white to signify safety, and consequently, in England, safety is signified by green, danger by red, and a signal showing white is to be regarded as a danger signal. In England, therefore, there is no distinctive color for a distant signal. Red is used, and the fact that it is a cautionary signal is shown only by its location along the track. In France the same colors are used for signals as in this country.

These colors are generally obtained by lights with white or colored lenses.

Day signals, both in this country and in foreign countries, may be

colored disks, the same colors being used as at night. Colored disks are generally used in France. They are used also on a number of roads in this country. However, it is generally conceded that a colored arm, projecting from a post, is a more distinctive signal than a disk, except, perhaps, in tunnels. For this reason the semaphore signal is used very extensively in this country, in England and in Germany.

The most common practice in this country requires that the post be about 20 feet high, painted white, and situated to the right of the track governed by its signals. The semaphore arm projects to the right of the post and is painted red in case it is a block, home or train-order signal; or green if it is a distant signal. In the last case the end of the semaphore is generally notched. However, practice is not uniform, even in this country. In the case of roads with more than two tracks, semaphores are placed on bridges and are then directly over the track governed.

In a horizontal position, a block, home or train-order signal signifies danger, or "stop." Inclined at an angle of 45° or over, it signifies safety, or, in case of a permissive block system, if inclined at an angle of less than 45°, it gives a train permission to go ahead under control. A green semaphore signifies caution when in a horizontal position, and safety when in an inclined position.

More than two semaphores are often arranged on the same post where they govern over two routes. In this case the upper blade generally controls the high-speed route, and the lower ones govern the routes in order from right to left. However, this practice is not entirely uniform, even in this country.

In order to fully protect a junction or a set of switches at a station by an interlocking system with sephamore signals and to secure a prompt and safe movement of traffic, signals have become quite numerous.

To show their variety, the attached statement is appended:

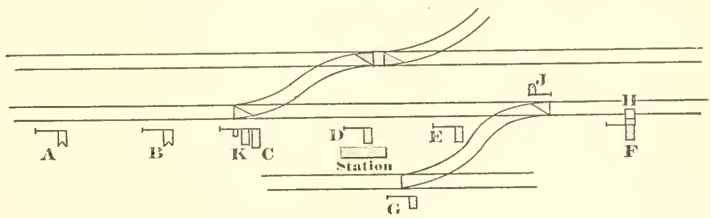

Fig. 1.

A.—First distant.

B.—Second distant, for suburban traffic or for very high-speed roads, say, ninety miles per hour.

C.—Rear home (a route signal).

D.—Home, protecting train standing at station.

E.—Starting, conveying order to start and covering siding switch.

F.—Advance. This is placed a train length in advance of siding switch to cover switching movements.

G.—Siding. This covers departure of trains from siding.

H.—Wrong track, governing west-bound movements on east-bound track.

J.—Shifting.

K.—Calling on signal. This signals trains to advance slowly past the tower for clearing home signal *D.*

The above list is given more especially to show how complicated a system of signals may become. It should be stated that the complication of signals is not looked upon with very much favor.

As intimated above, there is some difference of opinion as to the best form of signals. It is generally conceded that a very strong light, whatever its color, is the best for night. Some, however, wish to adhere to the position plan and go to considerable expense in order to illuminate their semaphores at night, as in the Koyle signal and the Union Switch and Signal Co.'s hollow box blade. There are others who think a disk is suitable for day, and confine themselves to the color method by day, and who are also able to use the same form of disk and the same colors as at night. Some recommend, for block signals, a form of signals different from that used for interlocking. This would allow of the use of a disk signal for blocking and a semaphore for interlocking. The Boston and Albany Railroad uses two white lights placed in horizontal position for danger, and two green lights placed in a vertical position for clear. The Old Colony Railroad has two red lights placed horizontally for danger and two white lights placed vertically for clear. In this way they secure position signals at night, just the same as by day by the use of the semaphore.

Having described the signals, it is necessary to describe their method of operation. In interlocking plants, both the switches and signals are controlled and thrown by an operator in a tower or signal station located generally near the switches. In case a mechanical device is used, a Saxby & Farmer or a Stevens machine is used, either in original form or as modified by recent improvements These improvements have been very great in the last ten years. A lever is not only provided to throw switches and signals easily, but the switches and signals are all interlocked by a series of locking-dogs or their equivalent, so arranged on the machine that no switch can be thrown without its corresponding signal and that a signal, even for a desired route, cannot be given until all the switches have been safely placed for that movement. By such a machine, switches 1,200 feet distant from a tower in each direction can

be thrown by pipes of 1¼ inches diameter, which are used to transmit the motion ; and signals distant about 3,000 feet, on each side of the tower, can be operated by the use of double wires. I will not attempt to go into the details of these machines and their connections.

An improvement on this method of throwing switches and signals is obtained through the use of compressed air. In the system known as the Westinghouse electro-pneumatic, controlled by the Union Switch and Signal Co., both switches and signals are thrown by air under a pressure of forty pounds per square inch. The air necessary for this purpose is compressed by pumps located at or near the signal station, and is conveyed in pipes to whatever switch or signal it may be desired to operate. This switch or signal may be several miles distant from the tower. At each switch or signal is a cylinder, with a piston, and air is conveyed to the signal piston through valves, which are operated by electricity. In the case of the switch cylinders, the air acts on oil, which latter conveys the motion directly to the piston, the air valves being opened by electricity. With this system the operator has only to turn a small switch, no larger than an ordinary electric switch, in order to throw any switch or signal connected with the signal plant, covering, as stated above, several miles in extent. This system requires a plant for compressing air, careful laying of pipe lines and the necessary mechanism at the switches and signals to move them. It also requires a telegraph line, so that electricity can be used for opening the valves and for locking them. The switches and signals are interlocked, the same as in the mechanical plants already described, the interlocking device being located in the tower, but occupying a very small space as compared with that required for the mechanical device. In the tower is always placed a tell-tale apparatus, on which is reported every movement taking place in the track ; and this movement is not shown on the tell-tale apparatus until it is completed in track. Electric bells and annunciators, for showing the location of trains, complete the system. The Stewart Avenue Plant, Chicago, is the latest one of this system installed. By this plant, 86 signals, 37 single switches, 22 double slip switches and 22 movable frogs are thrown by a machine having only 90 levers and occuying a space of 5 x 24 feet. A mechanical machine, to do this same work, would require 187 levers, and the machine would occupy a space of 14 x 77 feet. All signals are lighted by electricity supplied from the power-house.

A pneumatic system, as described above, is also used for block signaling over long distances. The system is used at many important points on the Pennsylvania Railroad. At Jersey City three trains can pass over the same track out of that station within 1½ minutes under the operation of this system.

This system is applicable to very large plants. It is too expensive

for small interlocking plants, or even for those of ordinary size. It is undoubtedly the most complete system of its kind at present in use anywhere.

In Italy, glycerine has been used to transmit motion for switches and signals, as also an unfreezing mixture of water; but the hydraulic pressure used there is from 50 to 60 atmospheres, and this pressure is too great for very successful use.

At St. Louis bridge a hydraulic pressure system was first used in 1883, controlling tracks along a distance of three miles, and operating switches on twenty-eight miles of sidings. This was not an entire success, however, and air is now used to transmit the motion, but hydraulic pressure is used at the valves. This plant consists of 108 levers, throwing 138 switches and signals, and handling about 131 trains daily.

Another system, striving for the same end as that of the Union Switch and Signal Co., is a new one recently brought out by the Electric and Auto-pneumatic Railway Signal Co., Rochester, N. Y., and now being tried. This is strictly a pneumatic system, but, in this case, not only are the switches and signals moved by compressed air, but the interlocking of the switches and signals is secured through the same means, and the pressure of air necessary for operating the switches and signals is only ten pounds per square inch. A plant of this form has recently been put in use on the Delaware, Lackawanna and Western Railroad at Buffalo, N. Y. The movement of the switches and signals is controlled by a small lever and a seven-way valve. It is through this peculiar valve that the interlocking is secured.

Electricity also has been used in interlocking apparatus; *i. e.*, electricity both for throwing switches and for throwing signals, as well as interlocking them. The Ramsey-Weir interlocking apparatus, which is being tried on the Cincinnati, Hamilton and Dayton Railroad, Cincinnati, is an example. The power is obtained from a gasoline engine operating an Edison dynamo of 125 volts, and a storage battery, which is charged every twenty-four hours by a dynamo working for eight hours. The plant, operated in this manner, consists of ten switches and ten signals. The cost of fuel for the engine is placed at seventy-five cents per day. The apparatus, as a whole, is very complicated and its success has not yet been entirely proved.

The most complete purely electrical system is the Siemens-Halske, of Germany. This system is used for blocking as well as for interlocking. The signals are operated by a Siemens machine producing an alternating current generated by the operator turning a crank. This system has not yet been introduced in this country.

Having described the various signals and their operating plants in interlocking, it is proper to take up the details of

BLOCK SIGNALING.

On very busy main lines the block system is required for perfectly safe operation; but the kind of system to be adopted depends upon the character of the traffic, and considerable study is necessary to determine what is necessary and best in any given case. The systems of operation are the train-staff system, the telegraph block, the controlled manual block and the automatic system.

The electric train-staff system is very much used in England, and is considered the safest for single track. The Webb & Thomson form requires, at every block station, an operator, and a patent staff machine, which is about 5 feet high and is provided with a slot to receive the train staves, which are each about 15 inches long. At the top of the machine are an electrical lock, an annunciator and a key for communicating with adjacent block stations. The construction of the machine is such that only one staff can be taken out of it at a time, and, having been taken out of the machine in the first station, the staff must be deposited in the machine in the second station before a second one can be issued from the first station. Likewise, Station 2 cannot issue a staff for a train bound for Station 1 if Station 1 has already issued one. The staves are readily exchanged between an engineman and a signalman on route. In case of moderate speeds a bag is used, with an apparatus working on the same principal as a mail crane.

Another machine on the same principle, but more compact, is Tyre's Train Tablet Apparatus. The working of the block is exactly the same as that above described, but in this case, instead of using iron staves, small iron tablets are used. An engineman, holding either a train staff or a train tablet, has an absolute right on the section to which it belongs, it being equivalent to an absolute train order; and it is utterly impossible for a train, moving in either the same or an opposite direction, to get upon the same block with another under the block rules.

The operation of this absolute block system requires no block or order signals whatever, but they may be used to give notice of staff.

The telegraphic block system calls for signal stations at the ends of all blocks, and the block signals should be controlled by signalmen only. The normal position of the signal should be at danger, so that they shall require clearing in order to allow a train to pass. Signals should be restored to danger after the rear of a train has cleared the signal station a distance of 100 yards. The operator at that station is then in position to report to the preceding station, or to the dispatcher, that that block is clear. In this system, either the home signal should be placed in advance of switches near the station, or a starting signal should be placed in advance of the home signal and in advance of all switches, this to be interlocked with the block signals and to be used for starting trains. The simple telegraph system secures no check on the operators.

The Mozier system, which is extensively used on the New York, Lake Erie and Western Railroad, is an improvement on the simple telegraph block. The block signals are arranged for three positions. A semaphore in a horizontal position by day, or a red light by night, signifies danger; the semaphore inclined upward by day, or a green light by night, signifies caution; and a semaphore inclined downward at an angle of 45° by day, or a white light by night, signifies safety. As operated on the New York, Lake Erie and Western Railroad, the cautionary signal is not used for passenger trains; in other words, passenger trains are run under an absolute block system, while freight trains are run on the permissive block system, using the cautionary signal. All trains are under the direct control of the dispatcher. The operator's key is locked with the signal, so that it cannot be used unless the signal is at danger. The operator sets his signal under the direction of the dispatcher, who orders red, green or white as desired on the approach of a train reported by the operator. The dispatcher signs his initials, and the operator repeats the order. To adopt this system over the old form of train orders required an increase of 40 per cent. in the number of train orders, but the orders are very short, and it is reported that the system is liked by both the dispatchers and operators, and that an increased amount of traffic is handled. No distant signals at block stations are used, and, therefore, an accident is possible in case of freight trains using the permissive block.

The Controlled Manual Block system requires that the operator shall not be able to give a clear signal for a second train until the advance block has been cleared. It requires, further, that all sidings shall be interlocked at the block stations. It is further recommended that a bell or other audible signal be attached to such switches in a block as may not be interlocked, so that information may be given to the train about to use such main-line switch to leave a siding when the block is clear. The use of the Sykes Block system, with all switches interlocked, covers these requirements. This system is in extensive use on the New York Central and Hudson River Railroad, and on the New York, New Haven and Hartford Railroad, as well as some others.

The Sykes system calls for an electric locking device, enclosed in a small box, which is placed in the signal station at the end of each block, these instruments being connected together by wire. A miniature semaphore arm over the box shows whether the advance block is clear or not. In addition to this, an annunciator shows whether or not the signal lever is locked.

With three signal stations (*A*, *B* and *C*), *A*, having a train for *B*, signals him accordingly by bell. If *B* is ready to receive the train he presses a plunger in his instrument, which causes the words "Train On"

to appear in the opening in his instrument, the word "Locked" to disappear in the opening in *A's* instrument and the word "Free" to take its place. *B's* plunger is locked and remains so until the train has passed his home signal, while simultaneously *A's* starting signal is unlocked. He lowers it and allows the train to go towards *B*. This action, however, brings forward the word "Locked" in *A's* instrument. *A* then raises the starting signal to danger, and it cannot be lowered again without *B's* permission. Before *B* can lower his starting signal, the train must pass an insulated section of track at his station, and he must go through the same action with *C* that *A* has previously gone through with *B*. Further, *B* is obliged to raise the starting signal to danger behind the train he forwards to *C*, before he can permit *A* to send him another train.

It is, therefore, an absolute block in every sense of the word.

In its most complete form, the system calls for home, advance and distant signals at each block, and requires the release of these signals to take place in the order : *home*, *advance* and *distant*. It further requires the electric control of outlying switches. This is accomplished by derails in every siding connecting with siding switch through one lever in a small hut at the switch, and an electrical lock is placed on this lever, which is controlled at the tower at the outgoing end of the block. The tower and hut are connected by a bell code. The detail is in use on both the roads above named.

On the New York Central and Hudson River Railroad, in order to secure the best possible service, a special cable is used for the wires in the system. It is an eight-conductor, aërial cable, suspended 12 feet above the ground on Western Union telegraph poles, with an intermediate pole, the cable being supported by a No. 6 iron wire.

In case of the failure of the electric line under this system, the operator on the New York Central and Hudson River Railroad is not allowed, under any circumstances, to unlock his Sykes instrument. But the operator, knowing that his advance block is in proper condition, allows a train to go forward under a written order, thus temporarily reducing the block from absolute to permissive.

The Sykes' system is used in the Fourth Avenue tunnel, Harlem. The disk signals here used are supplemented by torpedo-exploders and gong-signals. The torpedoes may be placed on the track ahead of a train and the gongs may, if necessary, be sounded by the action of the operator at any time during the passage of a train. Both of these signals are in harmony with the visual signals. Further than this, in the cabin is shown the position of all signals in the tunnel, and the condition of every light is shown by a simple device acting in such a manner that when a light is out the continuous electrical current is broken

by the contraction of two zinc strips placed close to the light. In this case, the automatic signals are used in addition to the Sykes system, the automatic blocks being properly overlapped, and all these visual signals go to danger upon the passage of a train, these automatic signals being operated through a track circuit. As a double check on the entire system, all the distant automatic signals are controlled by the wire circuit, and home signals by the track circuit. Under ordinary circumstances, therefore, the automatic system is used in this tunnel, and the Sykes system is put in use whenever, from any reason, the automatic system fails.

Before the New York Central and Hudson River Railroad adopted the Sykes apparatus, it used extensively two forms of automatic signals —the " pneumatic," and the " Hall "—but it was found that these automatic signals could not be worked under absolute rules. Engines had to be allowed to pass the block signal at danger, provided they waited a time interval ; and any automatic signal must have such a rule. It was for this reason that the Sykes system was adopted on the New York Central and Hudson River Railroad.

The Siemens-Halske system, already mentioned, is exactly similar to the Sykes in its results. The most important difference between the two is in the use of the electric current generated by the operator, instead of the battery circuit, to which, of course, there is some liability of accident in case of storm. In this system the power necessary to change a block is generated by the operator, who turns a crank at his locking instrument, twenty-one alternating currents being required for this purpose. This block system is not in use in this country at present.

Another form of controlled block system is the " Lattig," advanced by the National Switch and Signal Company, and claimed to be applicable to both single- and double-tracked railroads. By means of the adaptation of the electric slot to the signal, it is automatically set at danger by the passing of a train, and cannot be lowered by the signalman until the train has passed on to the next block. In other words, the signal is automatically set at danger and is so maintained, but is set to safety only by hand. The system may be used either with the wire circuit or with the track circuit. The latter, of course, gives the most complete protection while it is worked properly. In this system the current is always on. This requires considerable expense in maintaining batteries and they are liable to get out of order. Further, the electrical slot arrangement attached to each signal, in order to secure an absolute block, is a somewhat delicate apparatus and liable to get out of order. The system cannot be regarded as proved.

We will now pass to the *Automatic Block system.* To this system belongs the Westinghouse Pneumatic-Automatic, extensively used on the

Pennsylvania Railroad, also used on the Chicago, Burlington and Quincy Railroad; and on the Central Railroad of New Jersey. Fig. 2 shows the arrangement of signals on the Central Railroad of New Jersey.

In brief, the track is arranged with double or overlapping blocks, separate posts being furnished for each track. There are two blades on each post, the upper one red, with red lamp at night, and the lower one green, with a green lamp at night. When either of these blades is lowered to a safety position, a white light is shown at night, and an engineman passing a signal with the red arm lowered to safety and a green arm at danger position, must slack up and be prepared to stop at the next signal. The blocks are short, say, about one mile in length. The lengths of the blocks would naturally vary, with the traffic requirements of the road.

In this device the track circuit is used, consequently a block signal cannot go to safety while a train, or any portion of it, is in the block. This end is secured by the fact that the signals are locked to their danger position by electricity, and are placed in the circuit with the track. The

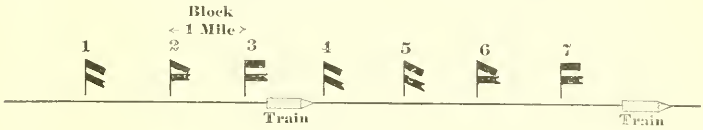

FIG. 2.

power to move the signal arms is derived from compressed air, conveyed in pipes along the track. This compressed air acts upon a piston enclosed in a cylinder placed at each signal, as described in detail under the head of Interlocking. The track circuit is so arranged, in passing through switches, that the circuit is not complete unless closed to the main line. Therefore, the signals cannot go to safety unless all switches are properly set. The system is a very complete one, but is expensive and is generally considered to be out of the reach of a single-track railroad. Of course, it is possible for these automatic signals to fail, from two causes:

(1) From any defect in the pipe line or in the cylinder attachment at the signals.

(2) From any failure in the working of the electric current.

In case of either of these failures, however, the signal goes to danger, in which event the train must proceed under special rules.

The Electric and Auto-Pneumatic Railway Signal Company, of Rochester, N. Y., is attempting to introduce a pneumatic block system carrying out its principle, which is described under the head of Interlocking. This system uses compressed air, both for moving the signals

and for locking them; also, for locking switches, and it does not use the electric circuit, and, therefore, does not attempt to protect the track so thoroughly as does the device of the Union Switch and Signal Company, already described.

The Hall Signal Company has a very complete automatic signal system extensively used on the Illinois Central Railroad. It is used also on the New York Central and Hudson River Railroad, New York, New Haven and Hartford Railroad, the Central Railroad of New Jersey, and many others. It is purely an electrical device, electricity being used to throw all signals. The signals are disks in three colors—red for danger, green for caution and white for safety. The night signal shows the same as the day signal. The block signals may be placed at any desired distance apart, and may be overlapped as much as may be thought necessary for safety on any given road. The signal may be operated by a wire circuit, in which case instruments, operated by the passing of a train to close the electric circuit, are used along the track. These track instruments have been proved to be a very complete and unfailing device.

A train, entering a block, passes a block track instrument which breaks the current, and the signal falls to danger. The same train, passing out of this block, goes over a clear-track instrument, which closes the circuit and raises the first signal to safety. The current is, therefore, closed except when a train is in the block or when a switch is open in the block.

In this scheme, therefore, the normal position of all signals is at safety. A signal will always drop to danger in case a train is in a block, or in case of an open switch or an accident to the apparatus.

The Hall signal may, however, be operated by a track circuit. In this case the rail circuit is made very complete by the detail of the wire fastenings used at the joints, and the rail current is carried through switches by means of a special switch instrument. The track is divided into blocks, the rails of which are insulated from each other. In the normal safety scheme, while there is no electrical contact between the two lines of rail in a block, the block signal is at safety. A train entering this block short-circuits the track battery through the wheels, and the signal falls to danger; or, in case a switch is open in the block, the signal circuit is broken and the signal falls to danger. A train passing out of this block causes the local signal battery to restore the signal to safety.

In the normal danger scheme, signals stand at danger, and are cleared only when an approaching train reaches a given point in advance of the block signal and in sight of the engineer. It is again dropped to danger when the train reaches it, and is locked so that it

cannot be cleared by a following train until the first one has passed out of the block and is under the protection of the succeeding signal.

This last scheme is a very complete and effective system of automatic block signaling, and costs but about one-third as much as the pneumatic-automatic system. Applied to a single-tracked railroad, its working is shown as follows (Fig. 3):

Head of train at A blocks opposing signal 2.

Head of train at 1 blocks signal 1 and opposing signal 4 ; opposing signal 2 remains at danger.

Rear of train at 2 clears signal 2 ; signals 4 and 1 remain at danger.

Head of train at 3 blocks signal 3 and opposing signal 6 ; signals 1 and 4 remain at danger.

Rear of train at 4 clears signals 1 and 4 ; 3 and 6 remain at danger.

Head of train at 5 blocks 5 and signals in advance, signals 3 and 6 remaining at danger.

Head of train at 6 clears signal 3 ; 5 remains at danger, etc., etc.

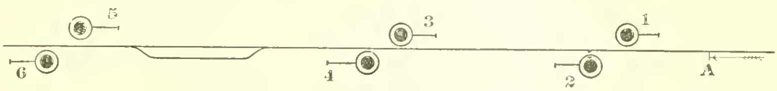

FIG. 3.

Upon a road which, under the controlled manual block system, required operators four miles apart to handle the traffic, the introduction of this system would enable the placing of the operators twelve miles apart, each operator having control of the signals at a passing siding through an interlocking board and tell-tale at his station.

The extension of this system announces trains approaching all block stations, passenger stations, road crossings and switches.

In attempting to make any comparison between the controlled manual system and the automatic system, it is generally considered that the manual signals are more liable to be obeyed by enginemen than the automatic, as disobedience of the former leads to a report from the operator, while no reports are possible in the latter case. In the case of accident to the automatic system, it is inert ; while in case of accident to the manual system men are at hand to take action to provide against accident and to straighten out obstructions to traffic. However, the cost of operating the manual system is greater than that of the automatic, in some of its forms (such as the "Hall") ; but, further, the automatic is applicable to a more complete protection of the track, road-crossings, etc., than is possible with the manual.

As compared with any telegraph or train-order system, block sig-

naling is generally considered more economical, as it affords a better protection of the track, and avoids danger of small rear collisions, and this to such an extent as to cover the cost of the blocking.

The devices mentioned show methods of protecting track and securing a constant check upon operators. The check upon engineers is not quite so complete, although their obedience to signals is in many cases assured dy derailing switches, and in other cases, as in tunnels, by the use of automatic torpedoes or gongs. Still further advancement is constantly being effected. The Electric and Auto-Pneumatic Railway Signal Co., of Rochester, N. Y., who are introducing a pneumatic block system, already described, have, in connection with their system, a shoe, which is placed between the rails opposite a danger signal, and which projects above the rail whenever the danger signal is not at safety. If, therefore, an engineer passes a danger signal, a projection from the engine, connecting with the air-cock of the air-brake system, strikes the shoe, and this action results in the setting of the brakes. This system is not fully proved.

The Rowell-Potter automatic block signal, which was used on the Intramural Railway, Chicago, uses a track-circuit system of block signals, and has also a bar which projects above the rail whenever the signal is at danger. This comes in contact with a rod extending below the front truck of the engine and provided with rollers on its end. This, striking the raised bar, opens the air valve and applies the brakes.

Of other devices many have been brought forward, but thus far not extensively used. One of these is the Kinsman Block system. It is a purely electrical device, and claims to stop trains without the agency of the engineer in case the block in advance is not clear, or in the event of an open switch or broken rail in the advance block In this system the track is divided into blocks two miles or less in length, and the track-circuit system is used. At the ends of the block is a guard rail, which is electrified in case the block controlled by it is not clear in every respect. An electric signal, displaying a disk, may be used in addition, if desired; but with this block system the visual signals are not regarded as absolutely necessary. Each engine is equipped with an arm, suspended between the wheels and adjusted to press against all guard rails, like the flange of a wheel. This arm is electrically connected with an instrument in the engine cab. The latter is directly attached to the air-brake pipe, and this, in turn, is connected with the cylinder of the throttle rod. In case an engine, so equipped, reaches an obstructed block, the suspended arm of the engine takes a current from the electrified guard rail, and the electrical instrument in the cab first acts independently of the engineer, to shut off the steam, and, by opening the air-valve, puts on all the brakes of the train.

The device in the engine cab is, I think, quite complete. The guard-rail device is not yet proved, and, I think, is inferior to the inducing magnets of the Wiley system. The signal recommended in connection with this system is not very good, but it is claimed that the engine equipment can be used with Hall signals, if desired.

This block system was first introduced in 1891. Experiments are now being made on three miles of the New York, Susquehanna and Western Railroad, and on twelve miles of the Chicago, Milwaukee and St. Paul Railroad. On the latter road it is reported by the railroad people that, on account of the electrified guard rails, the experiments are not yet wholly successful. In cost, this system does not vary much from the "Hall" System.

The Wiley Electric Block Signal system, with which the inventors are experimenting to a small extent on the Norfolk and Western Railroad, divides the road into blocks from one to five miles in length, and the wire-circuit system is used, requiring circuit-breakers in the track at each block. Its operation is similar to that of the Hall system wire-circuit, but it is probably cheaper in maintenance as well as in first cost. The signal, in its first form, is inferior, but the makers claim to have improvements under way.

This system may include an alarm signal bell in the cab of all engines, the bell being so arranged as to be sounded in case a danger signal is passed. Inducing magnets, located in the center of track at each signal, are energized whenever the signal is at danger, and similar magnets placed on the engine and suspended four inches over the rail, receive the current, which is conducted to the cab, where it serves to ring an alarm bell. This method of transmitting electricity from the track to the cab of an engine, seems to me to be the most complete I have yet seen, and superior to the Kinsman plan.

The devices last named require special equipment of every engine on the road; and so far they have not met with any very great favor among railroad men, it being feared that engineers would depend wholly on such signals as would be received in the engine cab, instead of being guided by track signals.

In conclusion, I have only to say that new devices and improvements in signaling are constantly being introduced; that many of these have merit, and that haste in adopting any given device is never expedient.

DISCUSSION.

Mr. G. R. Henderson.—I would like to ask a question regarding the old staff system, of which Mr. Churchill spoke. On a road, locked electrically or otherwise, how are the staves to be carried from one end of the section back to the other, and arranged so that other sections can take them up? Also, was there not some system used before the application of electricity?

Mr. C. S. Churchill.—The staves work exactly the same as an electrically-locked staff, except that there is no check or lock on the operator issuing. There is more than one staff—probably some number of staves. The trains running in the opposite direction bring them back.

Mr. M. E. Yeatman.—I think I can explain the system which Mr. Henderson has in mind. By the original staff system it would be impossible to work unless trains were running alternately in different directions, one train taking the staff and the other train bringing it back; but, of course, this rule is absolutely impracticable for general use, and it was very soon superseded by the staff and ticket system. Only one staff is used, but at each end a certain number of tickets or train-order forms are kept in a box, the key of which is attached to the staff, and it is therefore impossible for an operator to issue a ticket clearing a train over a section unless he has the staff. If he knows that two trains are passing, running in the same direction, he gives a ticket to the first and the staff to the second. After these two he could not send any more until the operator had sent the staff back over the section. The operator at the other end might have three trains. This, of course, would necessitate his giving a ticket to the first, a ticket to the second, and the staff to the third. This system would require electrical communication so that it might always be known what was coming. It requires something corresponding to our central dispatcher system, and it was in general use for single track roads when I was familiar with English train service.

The Chairman.—Mr. Churchill, I notice that you express no preference. You, no doubt, having gone through a study of all, have arrived at some conclusion as to which is best.

Mr. Churchill.—I stated that each of these systems is applicable to different conditions of a railroad. For instance, it is an open question between the Sykes system and the Westinghouse Pneumatic system on the New York Central Railroad and the Pennsylvania Railroad. There are two opinions. The New York Central uses the Sykes, and the Pennsylvania Railroad the Pneumatic. Each, as a matter of policy, would

certainly back its own system, and I think the results are probably about equal in both cases. The Sykes is rather the cheaper of the two.

The Chairman.—The Pneumatic, I believe, is the oldest system of automatic electrical signaling.

Mr. Churchill.—It preceded the Hall, although the Hall was the first electrical device. They have kept right alongside. I went over two sections of the New Jersey Central within the last six months. One of these is equipped with the Pneumatic and one with the Hall, consequently, I had a good chance to compare the two, and there is this to be said about them: With the Pneumatic, there is an air line to maintain. You are obliged to have a system of pipes to conduct the air for operating these signals, and an electrical system maintained to lock and unlock them, the track circuit being used on this road. When you come to the Hall, you have the track circuit and electricity operating the signals, but the motive power is electricity; so that, while in the Pneumatic we have to maintain not only the electricity but the air, in the Hall we have to maintain the electricity alone.

The Chairman.—Where the track is the instrument for carrying the circuit, what is the effect of a broken rail?

Mr. C. S. Churchill.—The signals would come to danger.

The Chairman.—And remain at danger?

Mr. C. S. Churchill.—Yes; for the protection of the train.

Mr. W. W. Coe.—That would hardly be considered objectionable when a broken rail is there.

The Chairman.—You have, no doubt, gone over a broken rail many a time.

Mr. C. S. Churchill.—Where the rails are not badly broken, and where the ends remain together, it would not affect the circuit; that is, provided you have a generally good track.

The Chairman.—You think the principal difference between the wo systems is in the cost of maintenance?

Mr. C. S. Churchill.—Between the two systems the first cost is the principal difference. The Pneumatic system is all right on a two- or four-track railroad, but would ruin a single-track railroad.

Mr. W. W. Coe.—Suppose the single-track road was going to grow—was in a progressive form?

Mr. C. S. Churchill.—It would cost something to locate it—something like $1,200 per mile for the Hall, as against $4,000 per mile for the Pneumatic.

Mr. W. W. Coe.—Two systems, one on single track and another on double track, would not do?

Mr. C. S. Churchill.—Not perfectly; still, they are so used, as in the case of the Hall and the Pneumatic on the New Jersey Central. I interviewed an operator there, and he expressed the opinion that there were fewer failures with the Hall than with the other. Understand, by failure I mean only the signal going to danger, owing to some defect in the signal plant. The blocking of the traffic amounted to but very little with either system.

Mr. W. W. Coe.—As I understand it, an engineer can accept a signal after it has been placed, and it is not required that he see it as it is being turned?

Mr. C. S. Churchill.—Well, he does see it in its normal condition. He accepts the signal as given, because, in case of trouble, it comes to danger automatically. I think the railroad people can see that the two systems are very nearly equal in their results. I mean as regards their automatic operation.

Mr. Soule.—I think there is one advantage that ought to be credited to the Westinghouse Pneumatic system, and which Mr. Churchill has not mentioned, and that is this: A great many signal engineers and practical railroad men have come to the conclusion that the semaphore signal is the only decent and acceptable form of signal for a railroad. Now, I do not think that any full-sized semaphore signal, such as is represented there, has ever been successfully operated by electricity, unless enclosed in a glass case and made on a reduced scale, and, in order to reduce its weight and inertia so that it can be operated by electricity and still have the semaphore of good size, it is necessary that the weight be reduced by having aluminum wire frames, with flannels or cloth stretched over them, and the whole enclosed in a glass case, and even then the glass case is likely to be obscured by rain, snow and ice, and the chances that the engineer will get a correct interpretation of this signal are correspondingly reduced. This must be considered in comparing the Pneumatic and electrical systems. The possibility of having a semaphore signal of any desired size, with a fixed and positive action, is an immense advantage in favor of the Pneumatic. It is getting to be not so much a change in color, as a change in position, which shall determine the meaning of the signals. I was quite familiar with railroad signaling up to three years ago. But Mr. Churchill's paper has made me realize that this is a progressive art—that it is going forward. I used to keep up with all of these devices, as mentioned in the mechanical papers, until the past three years, when I have not had the time for so doing. On the Pennsylvania Railroad I was identified with rail-

road signaling when it first began to be a serious question. The first effort they made to introduce an interlocking apparatus was when they sent to England, in 1874, and contracted for a track-signaling apparatus for the tracks at a junctional point, a simple double-track junction and cross-over. The apparatus was made in London, shipped over here and set up and put in operation by English mechanics. This gave an impetus to American inventors, and Towsey & Buchanan came to the front with their device. By 1876 the New York Central had constructed and put in operation four of these devices. When the Pennsylvania Railroad was getting ready for the Centennial, it was constructing tracks and bridges, but neglected signaling until the last moment, when I was detailed, on the 4th of March, to take up that problem, and was sent to Philadelphia in a hurry. The next day I was told that they wanted seven of these interlocking apparatuses, and that they were to be put in operation by the 7th of May. The General Manager, Chief Engineer and myself went over to New York, and the New York Central officials took us about and showed us all the interlocking apparatuses, and I was left there to study the subject. It was agreed that there was no time to order any apparatus from England, no time to undertake anything novel, and so we decided to avail ourselves of this system, and the New York Central people very kindly consented to lend us all the patterns. After taking a few castings for their own use, the entire outfit was shipped to Altoona, and got there by the 10th of March, and within these two months, before the 7th of May, all of the seven interlocking apparatuses had to be mapped out, made and got in running order. That apparatus was deficient in one essential principle. It did not include the feature of preliminary locking. That is, the modern apparatus is so made that as soon as the operator grasps the handle and closes his hand, so as to draw in the latch of the handle, the locking is accomplished preliminary to moving the lever. This simple grasping of the handle accomplishes the locking. Whereas, with this old style, the locking was not done until the end of the stroke. If certain others are to be unlocked, this is not done by the preliminary movement of the latch handle, but that unlocking is done when the latch snaps into the notch at the end of the stroke. Now this apparatus was deficient in that respect, and did not catch the principle of preliminary locking and the moving of the unlocking mechanism. When you were moving the lever, which was so arranged that you were moving that portion of the apparatus upon which it acted, you had no proof that it was unlocking until the stroke was completed, instead of at the outset. Consequently, every one of them put on the Pennsylvania Railroad in 1876, and some of them put on in two or three subsequent years, have been taken out and replaced by modern interlocking plants, where the principle of preliminary locking is carried out.

The Chairman.—We are obliged to Mr. Soule for his interesting history of railroad signaling on the Pennsylvania Railroad. It may be that Mr. Coe could add to it.

Mr. Coe.—It was very certain in keeping trains apart, but sometimes delayed the movement of the freight.

Mr. R. H. Soule.—I stated that there were seven interlockind plants of this pattern. This was originally intended, but a party nameg Burr, from New York, a lawyer, patentee, and a very clever fellow, inventor, and so on, cropped up, with a proposed system of interlocking and secured consent to put in a plant at one of the double-track junctions. It was very crude, but in all essential features was pneumatic—with a reservoir for the storage of air, and a system of piping running to all the switches and signals. There were no electrical features anywhere. There was a double line of pipes, a supply and return pipe, to and from each switch and signal, and the thing was operated quite successfully. Two or three disasters occurred, nothing serious, however. This was the first attempt at the pneumatic operation of signals and switches, and he got some pioneer patents, which resulted in litigation with the Union Switch and Signal Company, in which he was victorious, so that they had to make a settlement with him and bought in the patents, some of which are engrafted in their plant of to-day.

The Chairman.—Mr. Churchill, I would like to ask whether the tendency is not to disregard colors for signals, and if the position, rather than the color, is not relied on?

Mr. C. S. Churchill.—Well, that is a mooted question. I think that nearly every railroad will agree to go by the position of the signal during the day, and by the color at night. About a month ago I answered a lot of questions propounded by the Railroad Association of America, and about two days ago received advice of the replies. Replies from thirty-two of the roads were received, and, if I remember aright, twenty-eight were in favor of the semaphore signals by day and of color by night.

The Chairman.—Was it not then suggested that if the use of color by night were adopted, red would appear white to a certain extent, when snow was on the glass?

Mr. C. S. Churchill.—I think this point is strained. A good red light would show red, even if the snow was on it. Four of the roads wanted a green light for safety, as in the English system, the argument being that if a red light were to break a white light would appear. I do not think that the best glass is liable to break, and, even if it were to

break, it would not be liable to break so badly in one night that some of the red pieces would not be left there to show a red signal.

Another argument is, that in approaching a town, an engineer might mix up the town lights with the signal lights and possibly take a town light for a safety signal.

I think that if the make of lens is considered, and if you have a good, strong lens (I think the N. and W. R. R. switch lens in the Westlake lamp is an excellent one), there is no danger of mistaking it for a town light, no matter of what kind, and any good strong lens, carefully put in, produces the same effect. But it is a mooted question, railroad men are still discussing it, and I do not know how it will be decided. You see what it has led to in England; two colors for three signals. I think it is a great mistake to compel an engineer to remember two signals, both showing a red light, which is a danger signal in one case and a distant signal in the other. He may turn to fix his engine just as he is approaching a distant signal, and, by the time he looks up, he may have passed it, and he does not know whether it meant safety or not. Then when he comes to the danger signal, he cannot tell, unless he knows all about the country, whether it means danger or caution, and he is simply obliged to hold his train. If there is to be any change at all, we should still have three lights for the three signals, danger, distant or caution, and safety. In your first question, you asked about the comparative merits of the systems. It might be well to state here that the Pneumatic is better than the Hall in that it enables the operator to throw any switch in a block. This is a great advantage. Mr. Soule's point about these signals has, of course, considerable merit, and yet you will find, as I brought out, that in the tunnels in New York they use disks in preference, and the New York Central people write me that they will stick to the Hall, that, after using it, they find it answers their purpose better than any other automatic signal. Again, take a road like ours (the Norfolk and Western Railroad) a single-track road, with double-track work going on. It is not necessary to equip the whole line with a device like the Hall; or with a Pneumatic, at a great expense. To secure greater safety on a road with a telegraph block, like ours, you can make your block more rigid than at present; make it an absolute block, and then check your operators by using the Sykes system. The Johnson people are very enthusiastic in the praise of their system (the staff), but they admit that theirs is only for a single-track railroad, and we are double-tracking, so that the most progressive plan may be to put in the Sykes. When you desire to add automatic signals, you can do so, and still not throw away any of the plant then in use.

THE CONTRIBUTION BOX.

Members of the associated societies, and other persons, are invited to send to the Secretary, for this department of the JOURNAL, such matters of general interest as may come to their notice.

Wood Pavements in Australia.

Apropos of the valuable matter on road construction contributed to this number of the Journal by our new member, the Association of Engineers of Virginia, it may be of interest to quote as follows from a paper on "The Evolution of the Modern Road," read before the Victorian Institute of Engineers, in November last, by Mr. A. C. Mountain, City Surveyor of Melbourne, Australia.

"Wood-paving was first laid in Australia in 1880, when an experimental section was laid with various kinds of wood in King street, Sydney. The main principle of obtaining a firm and impervious foundation of concrete was adopted, and a ¾ in. joint between the rows of blocks was provided for. This latter was determined on at the desire of some of the authorities (who were naturally anxious to prevent a failure of the unknown material through slipperiness), but was soon found to be not only unnecessary, but detrimental to the life of the road, as it enabled the toes of the horses' shoes to work on the arrisses of the timber until, in time, the effect of a corduroy surface was produced, making the roadway very noisy. In 1885, perceiving this, I reduced the joint to ½ in.; and, in 1886, still more narrowed it to ⅜ in. As a matter of fact, experience has shown that, with proper attention to cleanliness, there is not much more danger, on the score of want of foothold, with hardwood than with sets, and that the joints may be regarded as adding but little to the safety of the road. In practice the paving in Melbourne has been laid for some years past with ¼ inch joints, with the exception of one section where the blocks were simply tarred and laid close together; but the great expansion of our red gum renders it doubtful whether there be any real advantage in this method.

The blocks are sawn in lengths of six inches out of 9x3 planks, and are laid on a foundation of good Portland cement concrete, varying from 6 to 9 inches in thickness according to the nature of the ground, brought to the proper gradient and convexity, the latter generally one in fifty, and worked smooth on surface by means of a "floating" or rendering of cement mortar. The length of six inches was chosen for the blocks, not because it was essential to have that depth to ensure a firm and substantial coating to the street, which it had been demonstrated can be obtained with a 4-inch block, but in order that when much worn on the top the blocks may be cut down in length and re-used on the work.

"As regards the cost of wood-paving, the latest work done in this city has been carried out, including excavation and 6 inches of concrete foundation, at the rate of 16s. 6d. per square yard. I have no knowledge of any similar work that has been done so cheaply. Even at this price, which is about four times the cost of a good macadamized road in Melbourne, it will readily be perceived that ultimately the wood becomes the cheaper pavement, if its durability is such that the saving in annual maintenance (as

compared with the cost of keeping the macadamized road in order) be more than will cover the difference between the original outlay cost of the two materials. This is entirely apart from the question of public comfort, cleanliness, and wear and tear on horse and vehicle, which must surely be valued for something."

Béton Armé.

A system of construction bearing this name (which may perhaps be freely translated "reinforced Beton," or "iron-clad Beton,") appears as a rival of the Monier system. Its inventor is M. Hennebique, a French engineer, and its chief claim appears to be that the materials used, the concrete and the iron, are exposed to those stresses which they are best adapted to resist, the iron, in beams, being placed chiefly in the lower part of the section, while the communication between the upper and lower portions is secured by the use of thin iron plates placed vertically, or nearly so, in the mass, after having been coated with a thin layer of cement mortar.

Another advantage claimed for the system is that iron in common and easily obtainable forms, such as flat, round and square bars, can be employed, thus securing cheapness of construction.

A number of buildings on this system have been constructed in Belgium, France and Western Switzerland, and a warehouse is now being built at Lausanne.

Electric Railways with Underground Conductors.

In these days of the almost universal sway of the trolley system, it may be interesting to note that the Blackpool Tramway, installed in 1885, has ever since been using underground conductors.

As originally installed, the slot was placed midway between the rails, but Mr. Holroyd Smith, in reconstructing the system, places it under one of the rails, which is divided for the purpose. The return circuit is through the rails, which are reinforced, where necessary, by a wire with which they are connected at intervals.

When the track is double, the conductor is placed under each of the inner rails, and in order to adapt the motors to this condition of things the collector is made movable transversely of the car.

Large cars recently furnished for this road have two four-wheeled trucks, with a motor on each truck, and eighty-two seats, including a considerable number on the roof.

The road is about two miles long, and, during the last seven years, has been operated by a company, but it has now passed under municipal control.

In first cost, the Holroyd Smith system is said to be more expensive than the trolley, but cheaper than the cable, while its cost of operation is fairly comparable with that of the trolley system.

The four lines of the Siemens-Halske underground-conductor system in Buda Pesth have been in operation since 1887.

Progress of Electrical Engineering.

It is significant of the progress recently made by electrical engineering that whereas only 32 of the 475 pages of the Association's Index to Cur-

rent Literature for the years 1884 to 1891 were devoted to electrical matters, about one-fourth of the items in the index for the current number pertain to such subjects.

Electrical Towing on the Bourgogne Canal, France.

The motive power for this work is derived from turbines established at two locks upon the canal. These turbines make one hundred revolutions per minute, and act directly upon the dynamos through a horizontal shaft. The current is conveyed to the line through three wires of 8 mm. diameter, supported upon poles and upon cross wires.

The towing boats are 49 feet long by 10½ feet wide, and draw less than 18 inches of water. They take the current from the line by means of trolleys at the ends of poles, which are made nearly 25 feet long in order to provide against the oscillations of the boat.

A battery of 250 accumulators has been installed at one of the power houses with a view of storing the force of the fall while the boats are idle, and delivering it up again when they are in motion. It would appear, however, that their installation was hardly justified, especially in view of their heavy cost, which amounted to about $3000. The cost of the entire electric towing plant was about $27,000.

From September 1, 1893, to April 1, 1894, there were transported by electricity 81,000 tons in 897 hours, at a cost of $1180, while during the corresponding period of the preceding year 78,600 tons were transported by steam in 917 hours at a cost of $1600. The comparison, however, covers a period of time too short to warrant the drawing of definite conclusions.

Improvement in the Roasting of Carbonate Iron Ores.

At the meeting of the French Society of Civil Engineers on February 1st, Mr. S. Jordan described an improved furnace by which he had greatly reduced the cost of roasting carbonate iron ores. Mr. Jordan found that in Cleveland, England, and in various places on the continent, from 30 to 40 kilograms of fine coal were required for the roasting of 1000 kilograms of raw carbonate. This appeared highly economical when compared with the consumption of coal in the calcining of limestone, which required a consumption about 3½ times as great. Mr. Jordan, however, succeeded in constructing at Bilbao a furnace where the consumption of coal per thousand kilograms was reduced from 30 or 40 to 4 kilograms. The furnace is nearly cylindrical, 4 meters in diameter and about 9½ meters high. It furnishes daily about 60 tons of roasted ore from 85 to 86 tons of crude ore.

In the construction of this furnace Mr. Jordan sought to provide that the ore should at first descend uniformly and in horizontal layers, becoming gradually warmed until it arrived at the zone of combustion, where the disengagement of the carbonic acid is completed. Below this level the resulting protoxide combines with an additional supply of oxygen to form peroxide.

In a larger plant now being constructed, the previous reduction of the fuel to a gaseous form is entirely abandoned.

The "Wobbling" of the Earth's Axis.

A writer in the Boston Journal discusses the facts recently brought out by astronomers and showing that the position of the poles upon the surface of the earth shifts through a small orbit in a period of something over a

year. The writer in question argues that, as the latitudes of points on the earth are thus shown to vary from one year to another, the locations of political boundaries that are fixed on parallels of latitude must vary likewise, and gives statistics of the area of land that must be in the United States in one year and in the Dominion of Canada in another year. Mr. N. Spofford, of Haverhill, Mass., who has been re-running the boundary between Massachusetts and New Hampshire, writes to the Haverhill Daily Bulletin to assure its readers that after a line has been once properly surveyed and monumented, any cavorting around of the parallels of latitude must be on their own responsibility.

THE LIBRARY.

It is proposed to notice briefly, in this department of the JOURNAL, such engineering publications as may find their way to our shelves.

Publishers are requested, in sending works for review, to state the prices of same.

Massachusetts State Board of Health. Report upon the Metropolitan Water Supply.

In accordance with an act of Legislature approved June 9, 1893, the State Board of Health has been considering the question of a water supply for the city of Boston and its suburbs within a radius of ten miles from the State House, and for such other cities and towns as, in its opinion, should be included in connection therewith.

The report of the Board is accompanied by those of the chief engineer, Mr. F. P. Stearns, and of the consulting engineer, Mr. Joseph P. Davis.

The cities and towns which it is believed desirable to include in the scheme have an aggregate population of 848,000.

The three sources which seemed worthy of critical examination are Lake Winnipiseogee, the Merrimac, above Lowell, and the Nashua, above Clinton. The last named was selected as in all respects decidedly preferable. An additional supply from the Assabet, Ware and Swift Rivers is contemplated in case of necessity.

The scheme involves the construction of a masonry dam 145 feet high and 1250 feet long, impounding water to a depth of 125 feet, on the Nashua River about a mile above Clinton. The lake above this dam will have an area of 6.56 square miles, an average depth of 46 feet, and a capacity of over 63,000 million gallons. The Swift River, if utilized, would require a still more formidable dam, 144 feet high, impounding a lake with an area of 37 square miles.

Steam Power and Mill Work. Principles and Modern Practice. By George William Sutcliffe, Mem. Inst. C. E. Whittaker & Co., London and New York, 1895. 877 pages, 5 x 7½ inches, and index. Illustrated. Price, $4.50.

While this work forms one of what is called the Specialist Series, it would seem to be designed rather for the enlightenment of those not previously conversant with the subjects treated, and for this purpose it seems to be admirably adapted.

Beginning with the first principles, those of heat and work, and passing on to the discussion of fuel and combustion, calorimeters, storage and treament of coal, the construction and behavior of boilers, etc., the author takes up the consideration of steam, its various properties, and its employment in the steam engine, the anatomy, physiology and hygiene of which are then treated.

The author then proceeds to consider, somewhat more briefly, various matters connected with machinery, such as toothed, belt and rope gearing, pulleys, shafting and its appliances, friction and lubrication, the corrosion of metals, hoisting apparatus, engine and machine foundations, and the design, choice and maintenance of engines and machinery.

The work is satisfactorily, though none too fully, illustrated, and the treatment is conscientious and the language clear.

City Engineer of the City of Omaha. Annual Report of the ——. December 31, 1894.

In the previous report, dated January 1, 1894, and noticed in the Library for March, 1894, the matter of prime importance seemed to be the question of constructing a canal for the purpose of bringing water power to the city, with a view to rendering the latter a great manufacturing centre. Judging from the present report, this question seems to have lapsed into innocuous desuetude, and the attention of the City Engineer is now devoted chiefly to the comparison of different forms of street paving. Mr. Rosewater, like some of his brethren farther east, has come into conflict with the disposition to draw specifications restricting the use of asphalt to that from one particular locality, and he makes no secret of his objection to the practice.

During the year, 14,000 lineal feet of sewers have been constructed, at a total cost of over $21,000. Little or nothing has been done in the way of street extension.

Mr. Rosewater claims that Omaha is the only city of its population in the United States that does not own its water works, and that the city can never secure the full benefits that it ought to have from a water-works system until it is the possessor of its own plant. He produces a diagram based upon Mr. Freeman's experiments and showing the height of discharge of effective fire streams through various lengths of hose and other nozzles of different sizes.

Conversion of Measurements in Different Units. Forty-three Graphic Tables and Diagrams for the ——. By Robert H. Smith, Assoc. Mem. Inst. C. E. London: Charles Griffin & Co. 1895. Price, 7s. 6d.

These graphic tables are embraced in twenty-eight plates, each measuring 10x10 inches, and divided into half-inch and tenth-inch squares.

The plates are very carefully executed and they cover the conversion of units of lengths and velocities, of areas, of volumes, of weights, masses and forces, of stresses (pressures per unit of area), of densities, of energy and work, of power and of temperatures.

As pointed out by the author, the graphic tables have, over numerical tables in general, the important advantages of continuity, of reciprocity, and of reducing the labor required and the liability to gross error.

The tables are largely, but not solely, devoted to the conversion of metric into English measurements, and vice versa.

Society Proceedings.

Institution of Civil Engineers. Minutes of Proceedings of the ——. Vol. CXIX. London. 1895.

Among the large number of valuable papers here presented we may note especially, as of interest to our readers, "The Removal of the Iron Gates of the River Danube," by O. Guttmann; "Cost of Dredging in the Lower Danube," by C. H. L. Kuhl; "The Concrete Bridge at Munderkingen," by K. Leibbrand; "The Filtration of the Muggel Lake Water Supply at Berlin," by H. Gill, late Chief Engineer of the Berlin Waterworks; "The Rajkol Waterworks, Bombay," by R. B. Booth; "The Rainfall discharged from Catchment-Areas," by W. K. Stent; and "Windmills for Raising Water," by J. A. Griffiths.

The death roll includes the famous names of Helmholtz, de Lesseps and Faija.

Professor D. C. Jackson's paper on the Corrosion of Iron Pipes by Electrolysis, and Mr. S. Whinery's paper on Asphalt Pavements, both from the September number of our Journal, are abstracted at considerable length.

American Society of Civil Engineers. Transactions of the ——. Vol. XXXIII. No. 1. January, 1895.

This number is devoted to Mr. J. A L. Waddell's elaborate and illustrated description of his Halstead street liftbridge in Chicago, and to the discussion thereupon, in which Messrs. Lindenthal, Buck, G. H. Thompson, F. W. Skinner, Charles E. Emery, J. S. Deans, Foster Crowell, Samuel T. Wagner, and others, take part.

A notable improvement has been effected by the use of the wax process for reproducing some (unfortunately, not all) of the illustrations, and the external appearance of the transactions has been vastly improved by the omission of the table of contents from the cover page.

New England Water Works Association. Journal of the ——. Vol. IX, No. 3. March, 1895. Quarterly, $2.00 per year; 75 cents per number.

Of the four papers presented in this number, that by Mr. E. D. Leavitt, describing "A few Examples of High-Grade Pumping Engines," was read June 15, 1894, and the other three at the adjourned quarterly meeting January 9, 1895. The latter are: "Eternal Vigilance the Price of Good Water, by G. F. Chace, superintendent, Taunton, Mass.; "The Capacity of Steam Fire Engines, Hydrants and Hose," by Dexter Brackett, assistant engineer, Boston; and "A Method of Connecting Lead Services," by W. F. Codd, superintendent, Nantucket, Mass.

An important matter of record is the resignation of Secretary R. C. P. Coggeshall, who has served the association, in various official capacities, ever since its organization in June, 1882, and to whose efforts its success is very largely due.

The communication in which the Association of Engineering Societies invited the co-operation of the New England Association is printed in full, as also the brief report of the Executive Committee, to the effect that it would not be advisable to accept the invitation.

Technology Quarterly. Massachusetts Institute of Technology. Vol. VII, No. 3. October, 1894.

Hon. George Duncan, of the Inst. C. E., contributes "Some Experience in Engineering Practice;" Mr. Louis Derr, "An Apparatus for Measuring Difference of Phase between Alternating Currents;" Messrs. A. A. Noyes and A. A. Clement, "The Electrolytic Reduction of Paranitrobenzoic Acid in Sulphuric Acid Solution;" Mr. George C. Whipple, "Some Operations on the Growth of Diatoms in Surface Waters;" and Professor Robert H. Richards, whose paper on "A New Prismatic Stadia," appeared in our journal for January, 1894, discusses "Close Sizing before Jigging," a title which, to the uninitiated, suggests the remark that the admirers of Sarah Bernhardt, in her lean estate, went in for "grace before meat." Upon examination, however, it transpires that the paper treats of the advisability of carefully assorting granular matters as to their sizes before passing them to the jigging machine.

ASSOCIATION OF ENGINEERING SOCIETIES.

Organized 1881.

VOL. XIV. APRIL, 1895. No. 4.

THE CHICAGO SANITARY DISTRICT CANAL.

III.* Description of the Work and the Methods of Construction on the Brighton Division.

BY ALEX. E. KASTL, MEMBER OF THE WESTERN SOCIETY OF ENGINEERS.

[Read February 6, 1895.†]

THE main channel on the Brighton Division ‡ extends from the intersection of Robey Street and the West Fork of the South Branch of the Chicago River, Chicago, Illinois, southwestward for a distance of 5.17 miles. The center line of the channel is approximately the center line of the right-of-way, which is bounded on the north by a line about 1,100 feet northward from and parallel to the north reserve line of the Illinois and Michigan Canal. The south boundary line is, in general, the north right-of-way line of the Santa Fé Railroad. The right-of-way of the Sanitary District is about 800 feet wide. The center line of the channel is a tangent throughout the Division. So far as known, the entire prism of the channel is in earth, mostly a hard, compact clay. The cross-

* Paper I of this series, Introductory, by Mr. Isham Randolph, appeared in the JOURNAL for March, 1895. Paper II has not yet been received.

† Manuscript received March 20, 1895.—*Secretary, Ass'n of Eng. Socs.*

‡ Since this paper was prepared, the Brighton Division has been abolished and the sections thereof, together with sections H and G, have been formed into a new division called the Corwith Division. A. E. K.

section is 110 feet wide at the bottom, with side slopes of 2 horizontal to 1 vertical. The center line, as laid out, is intended for the center line of the channel of 600,000 cubic feet per minute capacity. The channel which is now being excavated is of 300,000 cubic feet per minute capacity. On the north, the side of the channel at grade is 18.37 feet to the right of the center line, and, on the south, 91.63 feet to the left of the center line. At Robey Street the elevation of the grade of the bottom of the channel is —24.45 feet Chicago City Datum, and it then slopes uniformly at the rate of $\frac{1}{40000}$ to the end of the Division, where the elevation of grade is —25.13 feet. The cut of the channel varies from about 30 feet at Robey Street to about 38 feet at the end of the Division.

At the east or Robey Street end of the Division, the channel, for a distance of about 280 feet, widens out northward and continues full depth to the center thread of the West Fork of the South Branch of the Chicago River. This end is called the Basin. Its axis makes an angle of 68° 21′, east to north, with the center line of the channel, and its bottom width is about 260 feet. This makes an ample connection with the present navigable waterways of the city.

For convenience in construction, the Division is divided into six sections called O, N, M, L, K and I. Section O extends from the center line of Robey Street, station 38+89.7, to the south line of the right-of-way of the Chicago, Madison and Northern Railroad Company, station 109+11.7; Section N, from station 109+11.7 to the west line of the right-of-way of the 26th Street branch of the Atchison, Topeka and Santa Fé Railroad Company in Chicago, station 154+22.8; Section M, from station 154+22.8 to the west line of Crawford Avenue, station 182+81.0; Section L, from station 182+81.0 to the east line of the right-of-way of the Chicago and Western Indiana Belt Railroad, station 224+96.8; Section K from station 224+96.8 to station 268+46.0; and Section I, from station 268+46.0 to station 311+87.2.

Sections O and N.

The contract for sections O and N was let May 2, 1894.

The excavation on these sections is to be done mainly by steam dipper dredges, the excavated material being loaded into dump scows, towed out into Lake Michigan and dumped there. By the terms of the contract no excavated material is to be disposed of on the right-of-way, except as required by the Chief Engineer. Such material as is not needed by the Sanitary District becomes the property of the contractor, and he disposes of it, outside of the right-of-way of the Sanitary District, as he sees fit.

Collateral Channel.—Provision is made for a collateral channel from

the West Fork to the main channel. This channel is to be excavated to a depth of 12 feet below Chicago City Datum, 60 feet wide on the bottom with side slopes of 1½ to 1. At present this channel is located only from the West Fork to the north right-of-way line of the Chicago, Madison and Northern Railroad Company, its center line being about 755 feet east of and parallel to the center line of Kedzie Avenue. Up to January 1, 1895, only about 8,000 cubic yards of material had been excavated, and this by dry methods. The total amount of material to be excavated in this collateral channel is approximately 132,000 cubic yards. The collateral channel work is included in the contract for section O. On account of insufficient depth of water in the West Fork, west of Western Avenue, the dredging plant has not

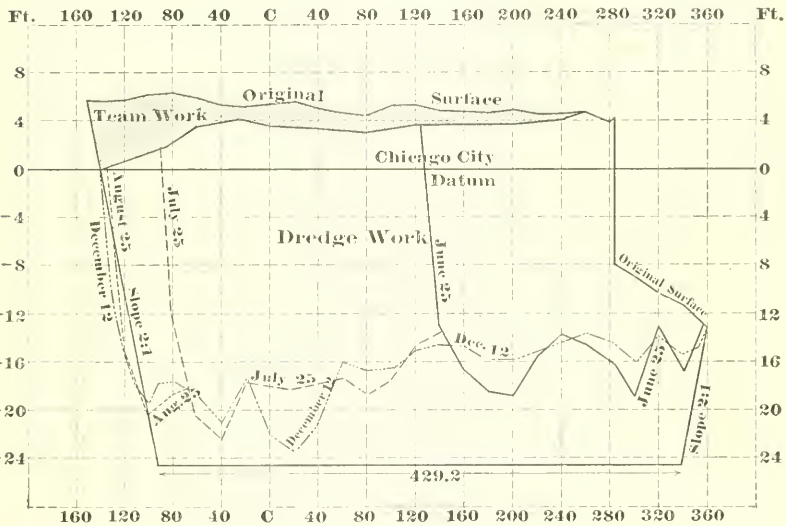

FIG. 1.—CROSS-SECTION AT STATION 40 + 50, SHOWING PROGRESS OF WORK IN THE BASIN.

yet been used on this work. However, it is expected that in the course of a few months the West Fork navigation will be improved, either by the City of Chicago or by the contractor, and then a dredging plant will be put on this part of the work. While the main use of the collateral channel during construction will be by the dredging plant, its main purpose is to provide, in the future, a navigable connection between the main channel and the West Fork. This feature has not yet been fully developed, and no further reference will be made to it, save to state that it was not projected solely to give the contractor access to the main channel work on the west end of section O and on section N.

Section O.—On section O the total amount of material to be excavated is 1,504,736 cubic yards. On January 1, 1895, about 517,000 cubic yards had been excavated. Of this amount 108,200 cubic yards have been excavated by dry methods and 408,800 cubic yards by steam dipper dredges. In the dry methods used the material is loosened with plows and removed with wheel scrapers, dump-cars drawn by horses, and railroad cars. The steam dipper dredges are of the ordinary type as seen in and about Chicago. Almost all the dredging plant has been used in this vicinity for a number of years. There is nothing particularly

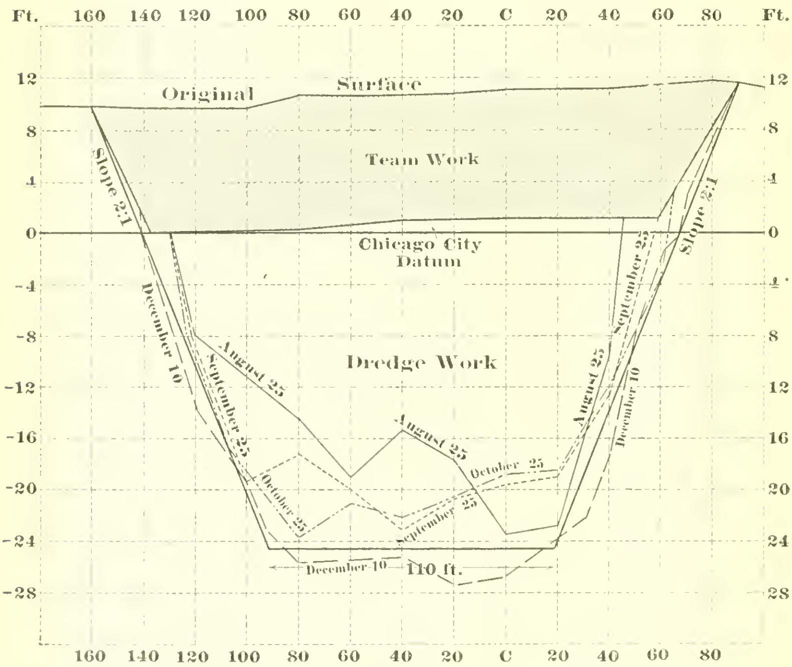

FIG. 2.—CROSS-SECTION AT STATION 52, SHOWING PROGRESS OF WORK IN THE MAIN CHANNEL.

novel in this method of doing the work. Up to the present time the dredging work has been confined entirely to that part of the channel between the centre line of Robey Street and the east line of Western Avenue Boulevard, a distance of a half mile. In this stretch the total amount of material to be excavated is 538,573 cubic yards. Of this amount all except about 40,000 cubic yards had been excavated on January 1, 1895.

The largest number of dredges employed at any one time was five,

FIG. 3.—View of the main channel looking westward from station 44, south bank, showing, on the left, portion of cut excavated by dry methods, and on the right, portion excavated by dredges. June 21, 1894.

FIG. 4.—View showing dredging plant at work; looking eastward from station 50. Dredge No. 9 is in the foreground. July 7, 1894.

FIG. 5.—View looking eastward, up the main channel from Western Avenue Boulevard. This part of the channel is almost finished, and the dredges are engaged in finishing side slopes. October 17, 1894.

but four were worked steadily all the season, which extended from May 15th to December 27th, 1894. The number of dump scows employed varied, as many as seventeen different ones being used on some days.

The following is a description of dredge No. 6, which is considered the best adapted for handling the material found :

Length over all	130 feet.
Width over all	38 "
Length of hull	90 "
Width of hull	32 "
Depth of hull	9 "
Draught	$4\frac{1}{2}$ "
Length of dipper-arm, wooden part	48 "
Length of dipper-arm, including dipper	58 "

Capacity of dipper, $2\frac{1}{2}$ cubic yards.
Hoisting chains, $1\frac{1}{4}$ inches.
Two high pressure double engines :

Cylinders of hoisting engine, 2—13″ x 16″.
Cylinders of swinging engine, 2—7″ x 16″.

Diameter of hoisting drum, 30 inches.
Boiler (locomotive) 6 feet by 14 feet.
Coal capacity, 60 tons.
Coal burned in 10 hours, $2\frac{1}{2}$ tons.
Dredging depth, 27 feet.
Electric lights for night work.

The following is a description of dredge No. 9, which has the best record for average output per shift of ten hours :

Length over all	130 feet.
Width over all	38 "
Length of hull	90 "
Width of hull	32 "
Depth of hull	9 "
Draught	$4\frac{1}{2}$ "
Lenth of dipper-arm, wooden part.	38 "
Length of dipper-arm, including dipper	48 "

Capacity of dipper, $3\frac{1}{3}$ cubic yards.
One-inch wire hoisting cables are used instead of chains.
Two high pressure double engines :

Cylinders of hoisting engine, 2—15″ x 18″.
Cylinders of swinging engine, 2—8″ x 12″.

Diameter of hoisting drum, 30 inches.
Boiler (locomotive), 4 feet by 12 feet.
Coal capacity, 40 tons.
Coal burned in 10 hours, $3\frac{1}{2}$ tons.
Dredging depth, 27 feet.
Electric lights for night work.
This is a boom dredge, the boom being suspended from shears. All the other dredges are crane dredges.

The dimensions of the other dredges do not differ very widely from the above.

The following is a description of the best type of dump scow, built of steel:

Length, 110 feet.
Width, 28 feet.
Depth of hold, 10 feet.
Draught $\begin{cases} \text{empty, } 2\frac{1}{2} \text{ feet.} \\ \text{loaded, 10 feet.} \end{cases}$
Capacity, 400 cubic yards, scow measurement.

The other dump scows are built of wood and vary as follows:

In length, from 96 feet to 115 feet.
In width, from 24 feet to 32 feet.
In depth of hold, from 8 feet to 10 feet.
In draught $\begin{cases} \text{empty, from 2 feet to 4 feet.} \\ \text{loaded, from 8 feet to 10 feet.} \end{cases}$
In capacity, from 230 cubic yards to 420 cubic yards.

Capacity of Plant.—From May 15th to December 11th the number of ten-hour shifts during which work was done was 661, and the number of scows loaded was 2,173. The total amount of material excavated and dumped into Lake Michigan was 400,262 cubic yards. The average output per ten-hour shift per dredge was 606 cubic yards, and the average load per scow was 184 cubic yards.

The largest average output per ten-hour shift per dredge during any month was 870 cubic yards, in July, and the least was 330 cubic yards, in November and December. During the latter months the dredges were mostly engaged in finishing the bottom and side slopes of the channel. The largest average scow load was 230 cubic yards, in August, and the least was 140 cubic yards, in November and December.

In considering the above data it is well to call attention to the fact that during all the season the dredges were worked at close quarters, and, therefore, could not be worked to the best advantage. This was due to the lack of right-of-way, the dredges not being able to proceed west of Western Avenue Boulevard. Part of the time it became necessary for one dredge to cut a channel ahead, casting the material on each side, in order to make room for the other dredges. Thus some of the material was handled twice. This would have been avoided had there been more ground to work over.

The following shows the largest day's work, done by each dredge, which came under our observation:

Dredge No. 3 loaded 8 scows in 10 hours, or about 1,400 cubic yards.
Dredge No. 6 loaded 5 scows in 10 hours, or about 900 cubic yards.

Dredge No. 9 loaded 10 scows in 10 hours, or about 1,800 cubic yards.
Dredge No. 13 loaded 7 scows in 10 hours or about 1,250 cubic yards.

The following shows the largest week's work done by each dredge:

Dredge No. 3 loaded 36 scows in 6 ten-hour shifts, or about 6,600 cubic yards, being an average output per 10 hours of 1,100 cubic yards. July 9th to 14th.

Dredge No. 6 loaded 40 scows in 12 ten-hour shifts—night and day work—or about 9,200 cubic yards, being an average output per 10 hours of 770 cubic yards. Time was lost waiting for scows. August 13th to 18th.

Dredge No. 9 loaded 48 scows in 6 ten-hour shifts, or about 9,200 cubic yards, being an average output per 10 hours of 1,530 cubic yards. June 19th to 25th.

Dredge No. 13 loaded 28 scows in 6 ten-hour shifts, or about 5,350 cubic yards, being an average output per 10 hours of 890 cubic yards. June 11th to 16th.

Description of Figures.

Fig. 1.—Cross-section at station 40 + 50, showing progress of work in the basin.

Fig. 2.—Cross-section at station 52, showing progress of work in the main channel.

Fig. 3.—View of the main channel looking westward from station 44, south bank, showing, on the left, portion of cut excavated by dry methods, and on the right, portion excavated by dredges. June 21, 1894.

Fig. 4.—View showing dredging plant at work; looking eastward from station 50. Dredge No. 9 is in the foreground. July 7, 1894.

Fig. 5.—View looking eastward, up the main channel from Western Avenue Boulevard. This part of the channel is almost finished, and the dredges are engaged in finishing side slopes. October 17, 1894.

Section N.—On Section N the total amount of material to be excavated is 1,105,443 cubic yards. On December 20, 1894, about 71,300 cubic yards had been excavated, leaving 1,034,143 cubic yards to be excavated. All this work was done by dry methods. Some of the excavated material was used in building a levee north of the main channel and in filling up clay holes. The balance was loaded into wagons and railroad cars, and used for grading purposes in various parts of the city. The railroad cars were loaded from temporary double-ended timber inclines built across the railroad track, and high enough to allow the cars to pass underneath. The material was taken up by wheel-scrapers, hauled up to top platform of incline and dumped through trap-doors into cars underneath, the empty scrapers passing down the other end of the incline.

The dredging plant could not get access to this section for reasons already referred to under the head of "Collateral Channel." This section is entirely surrounded by railroad lines, and up to the present time the right-of-way matters in connection therewith have not been fully adjusted.

The work on both sections, O and N, is being done by firms comprising the Illinois Dredging Company and Hayes Brothers.

Sections M and L.

The contract for sections M and L was let to the Heidenreich Company on December 27, 1893.

These sections extend from the west right-of-way line of the Santa Fé Railroad to the east right-of-way line of the Belt Railroad, about $1\frac{1}{3}$ miles. They are not crossed by any railroad lines nor by any public highways. The original surface was almost a perfectly flat prairie, the west end of Section L, being about one foot higher than the east end of Section M. This topographical feature enabled the contractors to use, under the most favorable conditions, the plant to be described later on.

The sections are worked together; the plant as designed, passing back and forth over both sections.

The total amount of material to be excavated is 1,811,731 cubic yards (Section M, 717,650 and Section L, 1,094,081). On December 24, 1894, about 801,870 cubic yards (Section M, 343,804 and Section L, 458,066) had been excavated, leaving 1,009,861 cubic yards (Section M, 373,846 and Section L, 636,015) to be excavated.

Of the amount thus far excavated about 178,387 cubic yards (Section M, 80,178, and Section L, 98,209) were taken out with wheel-scrapers, dump-cars and New Era graders, and the balance, 623,483 cubic yards (Section M, 263,626, and Section L, 359,857), was taken out with steam shovels in connection with inclined conveyors.

The team-work was undertaken more to keep up the contract requirements as to monthly progress than for any other reason. As soon as the excavating plant was fairly installed, the team-work was stopped.

Excavating Plant: Steam Shovels with Inclined Conveyors.—Four steam shovels are now in use. Each shovel travels on a path parallel to the center line, making a longitudinal cut. It loads the material into two cars, one at a time, and these are drawn by cable-hoisting machinery up an incline and automatically dumped from its apex. The incline moves alongside the channel at the same rate as the steam shovel, and the excavated material is dumped in a ridge parallel to the channel. When the plant reaches the end of the work, the steam shovel is turned around and the incline is moved toward the channel. Then another cut is made in the reverse direction. When two plants meet, the steam shovels pass each other and exchange inclines. The height of the finished spoil-bank will be about 30 feet. An 80-foot berm is left on each side of the channel.

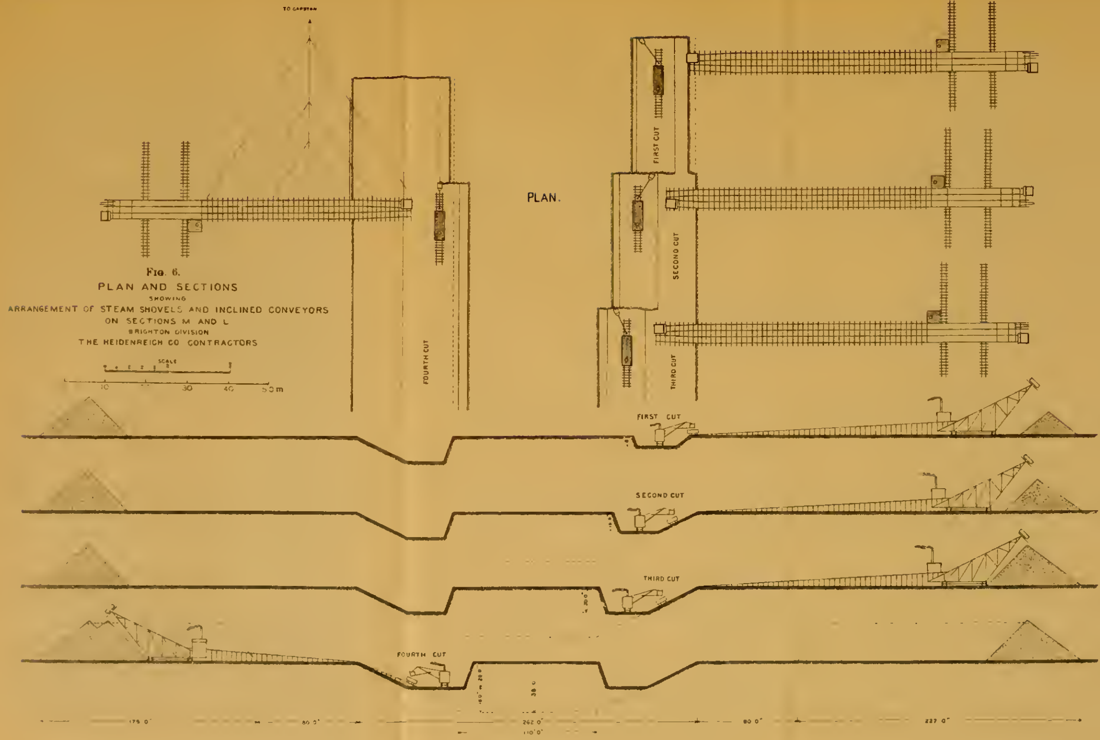

Fig. 6.
PLAN AND SECTIONS
SHOWING
ARRANGEMENT OF STEAM SHOVELS AND INCLINED CONVEYORS
ON SECTIONS M AND L
BRIGHTON DIVISION
THE HEIDENREICH CO CONTRACTORS

Description of Inclined Conveyor.—The inclined conveyor proper is about 80 feet long over all; its base is about 46 feet long; its height is about 34 feet, and its width 16 feet. The upper chords, on which rests the dump-car-track system, are about 80 feet long. The apex of the incline overhangs about 26 feet, and the end of the car tipple about 8 feet farther. The side elevation looks like an obtuse-angled isosceles triangle resting on one of the equal sides, the obtuse angle being about 130°.

The incline is mounted on two eight-wheel trucks which travel on two temporary railroad tracks of 3 feet gauge and 32 feet between centers. These railroad tracks are parallel to the channel. The truck nearest the channel side is lengthened out sufficiently to carry the

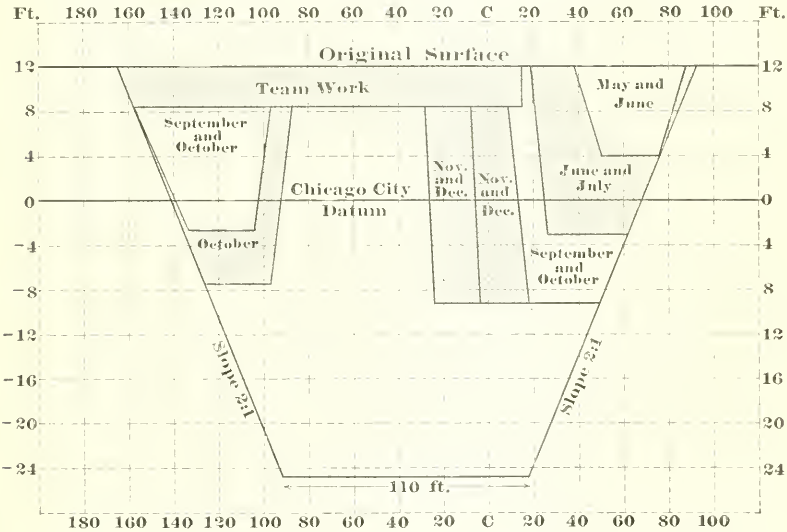

FIG. 7.—TYPICAL CROSS-SECTION SHOWING PROGRESS OF WORK TO DECEMBER 31, 1894. SECTION M.

boiler-room, which is adjacent to the incline. Part of the space in the interior of the incline nearest the channel is enclosed and contains the cable-hoisting machinery.

The approach from the channel side is made on a temporary timber-trestle. This trestle connects with the incline at a point about 10 feet above the ground, and descends uniformly to the edge of the slope. It then breaks grade and continues down the sloping sides to the steam shovel. The base of each bent of the trestle is a 6″ × 6″ timber, rounded upward at each end so as to serve as a runner.

The incline is moved ahead by means of a shaft geared to the car-

wheels and hoisting-engine; or, in some cases, by means of blocks and tackle, power being furnished by the hoisting-engine. The trestle approach is moved ahead with the incline by a system of light wire cables running to a capstan turned by horse-power. To prevent the approach from settling unevenly it is run across lines of planking laid at intervals. The bottoms of the runners are greased to reduce the friction.

The incline and its approach carry a standard gauge double track, 10 feet between centers. Two cars, each 9 feet long, 8 feet wide and 2 feet deep, are used. The front, or upper, end of each car is open. The cars are rated at 5 cubic yards.

The hoisting engine is a Mundy double-drum engine of 75 I. H. P.

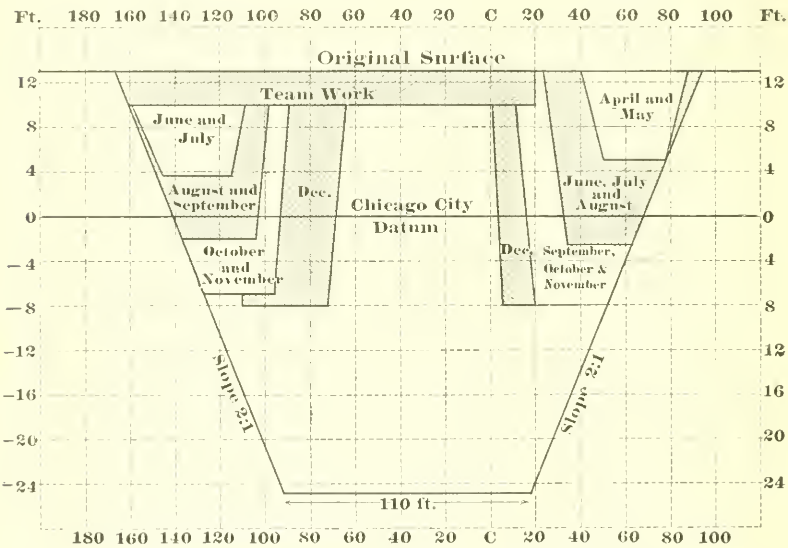

FIG. 8.—TYPICAL CROSS-SECTION SHOWING PROGRESS OF WORK TO DECEMBER 31, 1894. SECTION L.

The hoisting drums are 48 inches in diameter; ¾ or ⅞-inch wire hoisting cables are used. Each cable passes from its drum, underneath the incline, to a pulley at the end of the tipple, and then down the track to car.

Method of Working.—The method of working is as follows: One of the cars is put in position so that the steam shovel can load it. As soon as it is loaded, it is drawn up the trestle approach and the incline. On reaching the apex of the incline, where a short section of the track is pivoted on a horizontal axis, the weight of the loaded car and the tension of the cable cause the forward end of this section of track, or

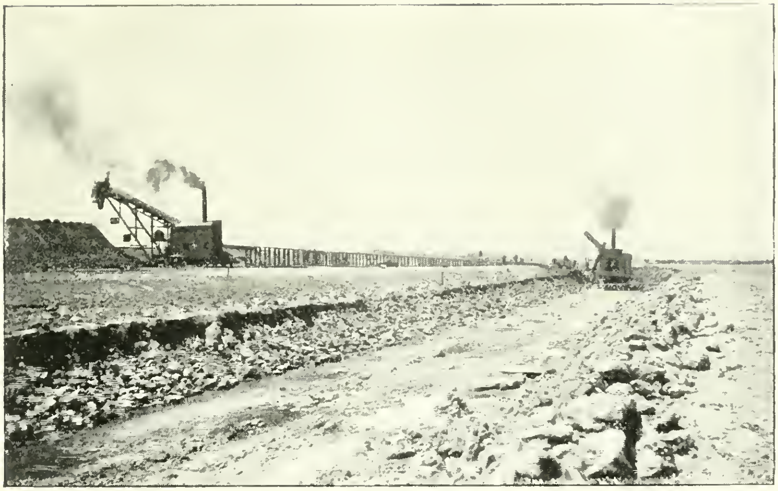

Fig. 9.—View showing inclined conveyor and steam shovel, south bank of main channel at about station 190, from station 187; working on second cut. One car dumped and one being loaded. Section L, June 29, 1894.

Fig. 10.—View showing steam shovel at work near station 165, north bank, loading car at channel end of inclined conveyor; empty car on top of bank; capstan for moving trestle approach on right of steam shovel dipper; second cut, looking northwest from station 164. Section M, June 29, 1894.

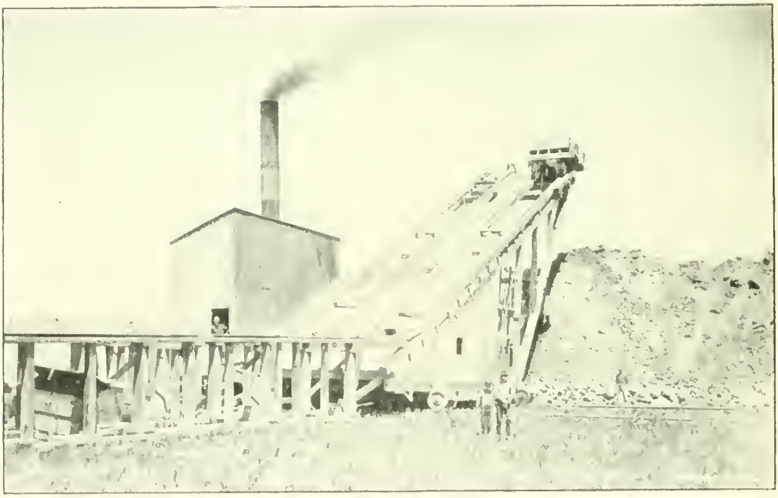

Fig. 11.—View showing incline; car on tipple about to dump; looking northwest. Section M, June 29, 1894.

tipple, as it is called, to drop, and the excavated material slides out of the car. As soon as the car is empty, and the tension on the cable released, the tipple is brought back into its normal position by counterbalances, and the car is again let down into the cut. In the meantime the other car has been loaded and is being hoisted. Generally, the empty car is returned to the channel side before the other car is fully loaded. Thus the cars are loaded and dumped alternately, and the shovel loses no time. When the shovel has to be moved ahead, the incline and its approach are moved ahead at the same time. The incline can be moved into a new position sooner than the steam shovel, and the latter can resume operations as soon as it is in position.

The tipple is provided with a system of hooks and catches which hold the car and prevent it from falling off when it dumps.

When a car is loaded, the engine-man is signaled to hoist it. When the car nearly reaches the top, it strikes a lever which operates an audible signal in the engine-room, thus informing the engine-man when to slow up and stop the engine. In the engine-room is also a visible signal which shows when the tipple has come back into position after dumping the car. The engine-man then releases his brake, and the car descends. The descent of the car is controlled by the signal-man at the channel side, who is able to stop the car at any point on the incline. This is done by a band-brake, on the hoisting drum, operated by the signal-man. In other words, each drum has two brakes, one of which, by a system of rods and levers, can also be operated from the channel side when the movement of the car is in plain view. By this system the engine-man is able to give his entire attention to the drum hoisting the other car, and there is less liability to accidents arising from mistakes in signaling. As a further precaution, each track is provided with a derailing switch placed on the trestle about 18 feet from the foot of the incline. In case the cable breaks while a car is near the top of the incline, the car could be thrown off the track, and much less damage done to life and property, than if it ran away into the cut. Fortunately it has not yet been necessary to use this appliance.

The excavation of the channel is made by a series of longitudinal cuts. In making the first cut the incline was placed in position just so far from the right-of-way line that when the material was dumped it would not spoil outside of the right-of-way. The first cut was about 8 feet deep and about 45 feet wide at the top, bounded on one side by the slope of the channel. The second cut was a widening and a deepening of the first cut, taking in about 25 feet of additional width and going down to 15 feet below the surface. The third cut extended out to about 80 feet from the slope stakes and to 20 feet in depth. After the third

cut the succeeding cuts were made of the same depth as the third, taking in 10 to 20 feet additional width of excavation at each cut.

The slopes are roughly dressed with the steam shovels, and then finished with plows, drag-scrapers and hand shovels.

At present there are three steam shovels and inclined conveyors on the north side of the channel and one on the south side, there being a greater spoil area on the north side. The first incline was put in operation on March 22d and the last on September 17, 1894.

Generally, after one cut is finished, the incline is moved a short distance, 5 feet or more, toward the channel, the trestle approach being shortened on the berm and lengthened in the cut.

It is proposed to complete the 20-foot cut clear across the channel and then repeat the operation for the remaining 18 feet or so of the required depth.

Working Capacity of Plant.—The largest average output of each steam shovel per ten-hour shift, during any month, was 968 cubic yards, in July, 1894, when 87,900 cubic yards were excavated in 90.8 ten-hour shifts. During that month, three plants were in operation, two working 12 hours per day all the month; and one, 12 hours per day to the 11th, and in two ten-hour shifts for the balance of the month.

The largest steam shovel output during any month was 93,700 cubic yards, in December, 1894, when the average output of each steam shovel per ten-hour shift was 808 cubic yards, there being 116 ten-hour shifts during which work was done. During that month four plants were in operation, two working each two ten-hour shifts per day and one working one ten-hour shift per day.

The smallest average output of each steam shovel per ten-hour shift was 662 cubic yards, in August, 1894.

In the above comparisons the first month, March, is not considered.

The total steam shovel output from March 22d, when the plant commenced operations, to December 24, 1894, was 623,483 cubic yards, excavated in 829.1 ten-hour shifts, making the average output of each steam shovel per ten-hour shift equal to 752 cubic yards.

Description of Figures.

Fig. 6.—Plan and sections showing arrangement of steam shovels and inclined conveyors.

Fig. 7.—Typical cross-section showing progress of work to December 31, 1894. Section M.

Fig. 8.—Typical cross-section showing progress of work to December 31, 1894. Section L.

Fig. 9.—View showing inclined conveyor and steam shovel, south bank of

main channel at about station 190, from station 187; working on second cut. One car dumped and one being loaded. Section L, June 29, 1894.

FIG. 10.—View showing steam shovel at work near station 165, north bank, loading car at channel end of inclined conveyor; empty car on top of bank; capstan for moving trestle approach on right of steam shovel dipper; second cut, looking northwest from station 164. Section M, June 29, 1894.

FIG. 11.—View showing incline; car on tipple about to dump; looking northwest. Section M, June 29, 1894.

SECTIONS K AND I.

The contract for Sections K and I was let to Christie & Lowe on December 27, 1893.

These sections extend from the east right-of-way line of the Western Indiana Belt Railroad south-westward for a distance of 8,690 feet. They are not crossed by any public highways and only by one double-track railroad line, which, however, is at the extreme east end of the work. The original surface was about the same as on Sections M and L, but slightly more rolling. The conditions were favorable for the use of the plant adopted by the contractors.

The sections are worked as one. The work was started near the east end of Section I and prosecuted in both directions.

The total amount of material to be excavated is 2,279,402 cubic yards (Section K, 1,147,753, and Section I, 1,131,649). On December 26, 1894, about 1,095,029 cubic yards (Section K, 414,618, and Section I, 680,411) had been excavated, leaving 1,184,373 cubic yards (Section K, 733,135 and Section I, 451,238,) to be excavated.

Of the amount thus far excavated, about 471,948 cubic yards (Section K, 263,170 and Section I, 208,778) were taken out with wheel-scrapers and New Era graders, and the balance, 623,081 cubic yards (Section K, 151,448 and Section I, 471,633) was taken out with steam shovels in connection with bridge conveyors.

Wheel-scraper and Grader Work.—On account of delays in securing the necessary material and machinery for installing the bridge conveyors, and in order to fulfill the contract requirements as to monthly progress while the excavating plant was being installed, the contractors put on a force of men and teams, using wheel-scrapers, New Era graders and wagons. By these means, a layer, 5 feet to 7 feet in depth, was removed all over the sections.

On Section K about 68,300 cubic yards were moved with wheel-scrapers. Work was done on 62 days, the daily average force being 59.6 men, 36.8 teams, 23.9 wheel scrapers, and 2.0 plows. The average output of each scraper per day worked was 46.1 cubic yards. Also, on Section K, about 194,900 cubic yards were moved with New Era graders

and wagons. Work was done on 123 days, the daily average force being 50.4 men, 41.9 teams, 3.1 New Era graders and 22.3 wagons. The average output of each grader, per day worked, was 508 cubic yards, and, for each wagon, 7.1 cubic yards. The spoil area on the north was between lines 80 and 290 feet from the edge of the channel, and on the south between lines 80 and 260 feet from the edge of the channel, the average haul being probably about 500 feet.

Excavating Plant: Steam Shovels with Bridge Conveyors.—The excavating plant now consists of four steam shovels, operated in connection with four bridge conveyors. The first plant was put in operation on March 29th and the fourth on October 5, 1894.

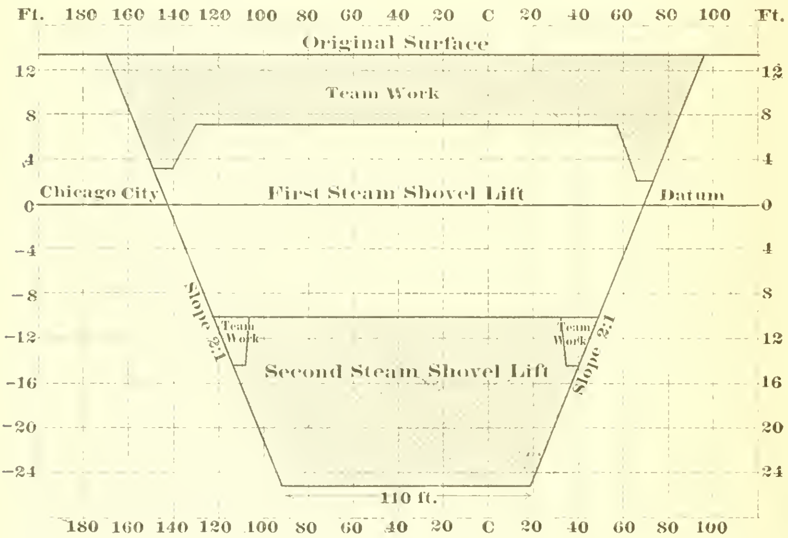

Fig. 13.—Typical Cross-section showing Method of Working Sections K and I.

The excavation of the channel was to be made in two cuts of about 22 feet and 16 feet in depth, respectively. However, on account of the work done with wheel-scrapers and graders, the first cut is now reduced to about 16 feet in depth for the steam shovels.

The excavation of each cut is made by two steam shovels, and the excavated material is removed to the spoil bank by the conveying systems, of which one works in connection with each steam shovel. The shovels work in opposite directions, one in each cut advancing eastward and one in each cut advancing westward. Each cut is finished from slope to slope as the work progresses. At the slopes, the work of the steam shovels is supplemented by manual labor, a small force of men

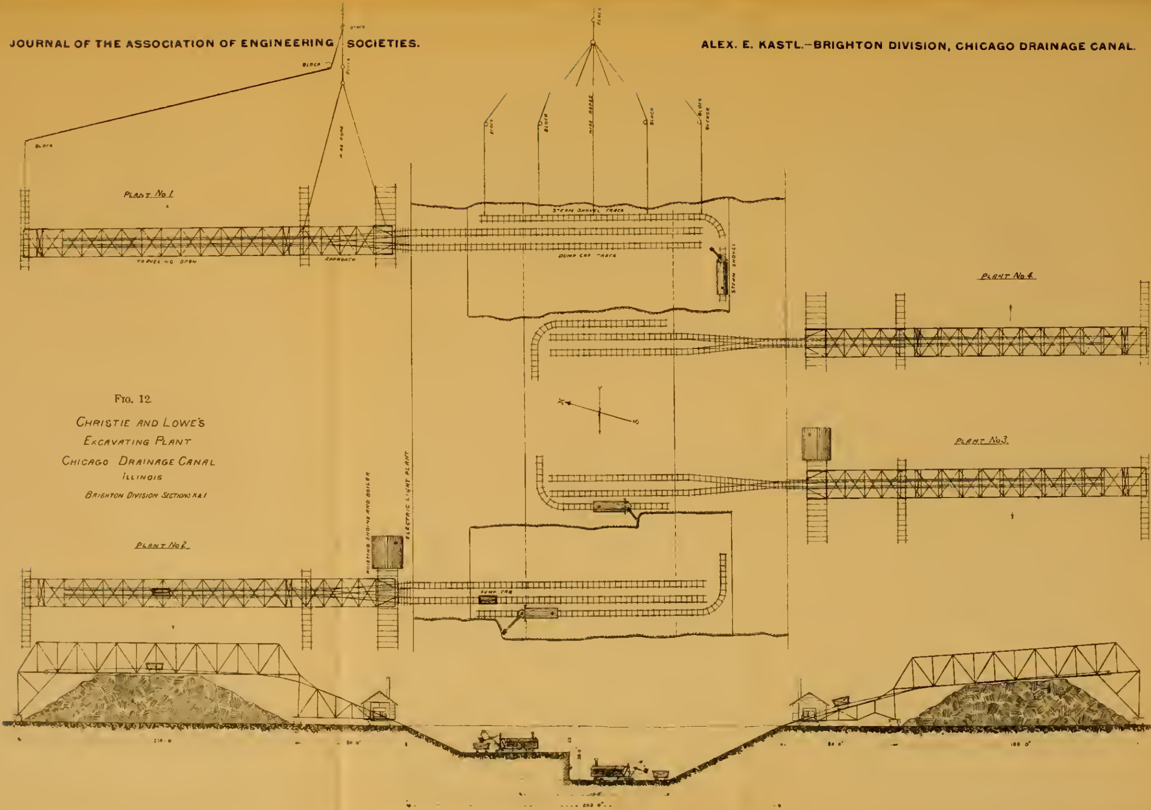

FIG. 12.

CHRISTIE AND LOWE'S
EXCAVATING PLANT
CHICAGO DRAINAGE CANAL
ILLINOIS
BRIGHTON DIVISION SECTIONS K & I

trimming the slopes and shoveling down such material as cannot be reached by the steam shovel. In order to reduce the manual labor on the slopes, a triangular cut, having the slope for one side, is made ahead of the steam shovels on each side with plows and wheel-scrapers, the material being wasted toward the center. The lower cut is finished to grade, the steam shovel wastage being shoveled by hand into the dump cars of the bridge conveyors.

The two conveyors for the upper cut are on the north side of the channel, where the spoil area is greater, and the two conveyors for the lower cut are on the south side of the channel.

Each conveyor consists of a riveted steel truss bridge, spanning the spoil area, with an inclined steel trestle approach between it and the edge of the channel. The bridge is supported by tower piers mounted on trucks, which travel on tracks parallel to the channel. The pier farthest away from the channel travels on a single track. The pier next to the channel is a part of the inclined trestle approach, which travels on two tracks of different gauges. The track next to the channel is of wider gauge, and the truck which travels on this track is made long enough to carry the power-house containing the boiler and the hoisting and electric lighting machinery. The bridge and incline carry a double track, which is continued down the slope and across the bottom of the cut. The tracks on the bridge overlap, a single-track structure being all that was required. This arrangement of the tracks obviates the use of switches.

Each bridge on the north side is of 210-foot span, and each one on the south side of 180-foot span. The bottom chords of the trusses are about 35 feet above the surface of the ground. The inclines are each 80 feet long, and the width of the berm is 80 feet also. The floor of the 210-foot bridge is level, while that of the 180-foot bridge slopes toward the channel at the rate of 1 in 20.

The steam shovel travels on a track laid across the bottom of the cut, next to the working face and parallel to the conveyor's pit tracks. The latter are near enough to the steam shovel's track to permit the steam shovel to load cars placed on the conveyor's tracks. In working, the steam shovel makes a cut across the channel, from slope to slope. At the side of the channel farthest from the conveyor the steam shovel's track curves (radius of curve, 30 ft.) backward and continues a short distance (25 feet) along the foot of the slope. The part of the track back of the curve can be separated from the main track. When it is desired to move the main track ahead for another transverse cut, the steam shovel is run back onto the short track.

The cars used with each conveyor are two in number, 8 feet long, 8 feet wide on top and 6 feet 7 inches at the bottom, and 4 feet 8½ inches

deep, with 9-inch sideboards. They are side-dumping, and they hold about 8 cubic yards each. While being dumped, the body of the car remains stationary, only the sides, which are hinged at the top, being moved. The cross-section of the material space of the car is shaped somewhat like the letter W, the center lines representing the floor and the side lines the doors. When the doors are released the material slides out. The apex of the floor is somewhat lower than the top edges of the car box (4 inches and 13 inches at ends and sides, respectively), The cars are alternately drawn on top of the bridge by cable hoisting machinery. The hoisting engine is of 100 H.P. The wire hoisting cable is one inch in diameter. It passes from the drum of the hoisting engine to a pulley underneath the incline, then underneath the floor of the incline and bridge to near the end of the latter, where it passes over a pulley and then back along the top of the floor to the car. Of course there are intermediate pulleys and rollers, which carry the cable in a proper manner. On the long spans another cable, ¾ inch in diameter, is used to pull the car back into the cut, while on the short spans the tail cable is dispensed with and the car descends by gravity as soon as the tension on the hoisting cable is released. Only one set of cables is used with each conveyor, the head and tail cables being coupled first to one car and then to the other.

Method of Working.—The method of working is as follows: One of the cars is put in position and is loaded by the steam shovel. Then the cables are attached and it is drawn up onto the bridge, where an attendant signals the engine-man when to stop. When the car is stopped at the proper place the attendant unlatches the levers holding the side doors in place, and the material slides out and falls through the bridge floor spaces onto the spoil area. As soon as the car is emptied, the side doors are automatically closed, and the attendant signals for the return of the car to the pit, where the car is again placed in position and the cables uncoupled and attached to the other car, which, in the meantime, has been loaded. Thus the cars are loaded and dumped alternately. When the steam shovel finishes its cut across the channel, it is moved back around the curve to the short piece of track, which is then disconnected from the main track. Then the whole system—bridge, incline and pit tracks—is moved ahead 15 to 20 feet. The movement is made by systems of cables which are attached to the bridge and pit tracks and which run to capstans and winches operated by animal power. When the tracks are in a new position, a section of track is placed in the space made in the steam shovel track, and the steam shovel is moved ahead to work on its new cut. It takes from 45 minutes to 1½ hours to move.

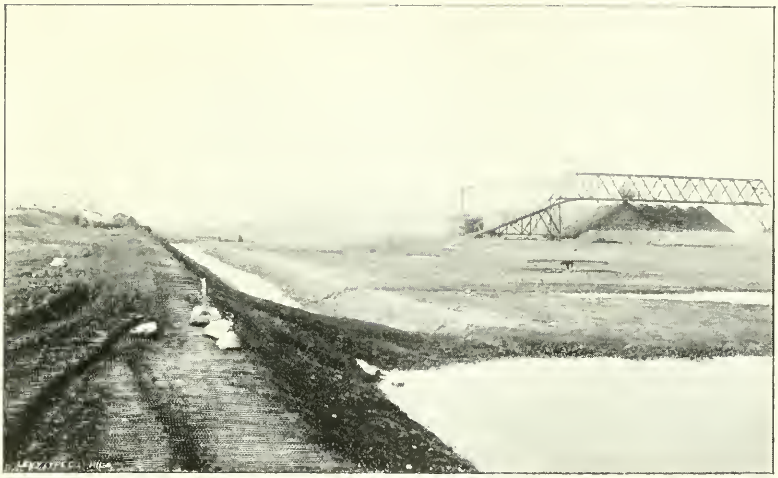

FIG. 14.—General view looking west, down the channel from left bank, showing in the foreground the upper cut as left after the team work. On the right are the two bridge conveyors for the upper cut, and on the left the two bridge conveyors for the lower cut. Triangular cut on the left and capstans on the right.

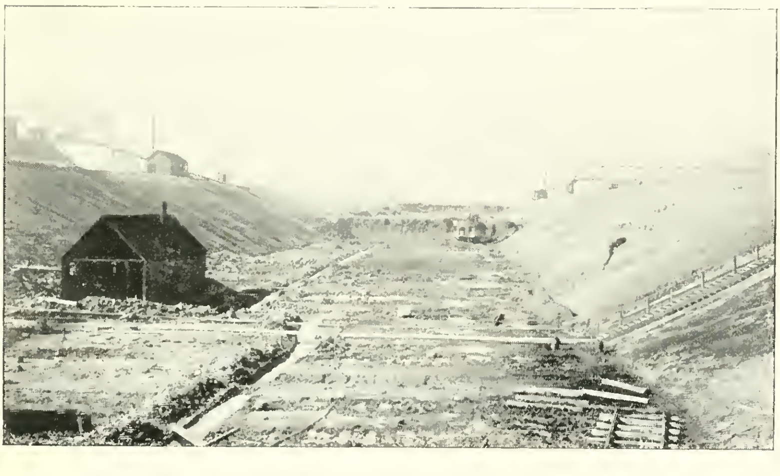

FIG. 15.—View looking west, down the channel, showing part of completed channel and lower and upper cuts, with steam shovels and conveyors working at the same. The pump-house is on the left over sump, to which ditches lead for draining the excavations of rain water. Completed channel, 110 feet wide at bottom, slopes 2 to 1, and 38 feet deep.

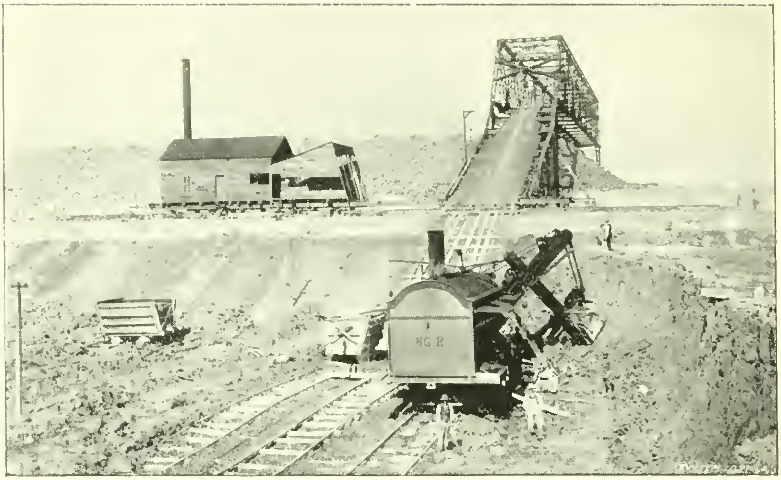

FIG. 16.—View looking north. End view of steam shovel, incline and 210-foot bridge at east end of upper cut. The steam shovel is at the end of its cut, which is about finished.

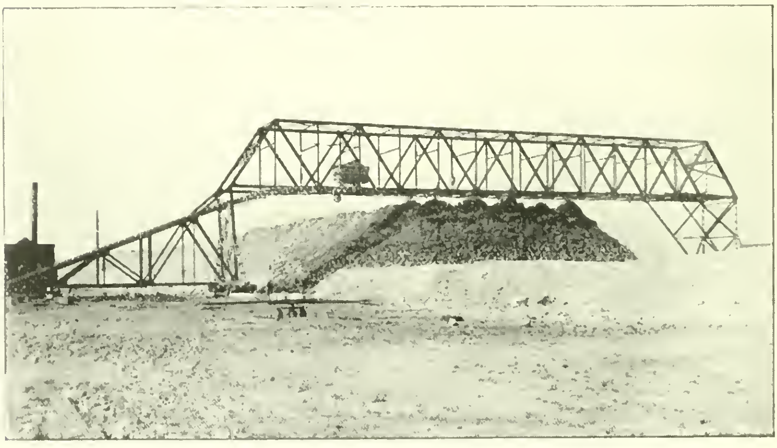

FIG. 17.—Side view of east 210-foot bridge and incline of first or upper cut; loaded car on bridge; note head and tail cables; capstan in the foreground.

The two plants on the lower cut leave a finished channel behind them.

On December 26th, about 2,100 feet of the channel were practically completed.

Working Capacity of Plant.—The largest average output of each steam shovel, per ten-hour shift, during any month, was 695 cubic yards, in December, 1894, when 109,805 cubic yards were excavated in 158 ten-hour shifts. During that month all four plants were in operation, working day and night ten-hour shifts during the first two-thirds of the month; during the balance of the month, two of the plants worked only day ten-hour shifts. A still larger average output is indicated during the month of June, when it was about 730 cubic yards per ten-hour shift, the total steam shovel output being estimated at about 38,000 cubic yards. During that month one plant was in operation, working in two ten-hour shifts per day. However, it must be said that on account of being involved with some team work, the June steam shovel output is not accurately known, the above being the most conservative estimate.

The largest steam shovel output during any month was 123,147 cubic yards, in November, 1894, when the average output of each steam shovel per ten-hour shift was 582 cubic yards, there beiny 211½ ten-hour shifts, during which work was done. During that month all four plants were in operation, each working in two ten-hour shifts per day of twenty-four hours.

The smallest average output of each steam shovel per ten-hour shift was 515 cubic yards and 570 cubic yards, in May and September, 1894, respectively.

In the foregoing comparisons the first two months, March and April, are not considered.

The total steam shovel output from March 29, when the plant commenced operations, to December 26, 1894, was 623,000 cubic yards, excavated in 1025 ten-hour shifts, making the average output of each steam shovel, per ten-hour shift, equal to 608 cubic yards.

Description of Figures.

Fig. 12.—Plan and sections showing arrangement of steam shovels and bridge conveyors.

Fig. 13.—Typical cross-section showing method of working Sections K and L.

Fig. 14.—General view looking west, down the channel from left bank, showing in the foreground the upper cut as left after the team work. On the right are the two bridge conveyors for the upper cut, and on the left the two bridge conveyors for the lower cut. Triangular cut on the left and capstans on the right.

Fig. 15.—View looking west, down the channel, showing part of completed

channel and lower and upper cuts, with steam shovels and conveyors working at the same. The pump-house is on the left over sump, to which ditches lead for draining the excavations of rain water. Completed channel, 110 feet wide at bottom, slopes 2 to 1, and 38 feet deep.

FIG. 16.—View looking north. End view of steam shovel, incline and 210-foot bridge at east end of upper cut. The steam shovel is at the end of its cut, which is about finished.

FIG. 17.—Side view of east 210-foot bridge and incline of first or upper cut; loaded car on bridge; note head and tail cables; capstan in the foreground.

RAILWAY LOCATION AND CONSTRUCTION AS PRACTISED IN THE WESTERN STATES.

By W. B. Lawson, Member of the Denver Society of Civil Engineers.

[Read September 5, 1894.*]

The primary intent of this paper is to place before the reader an outline sketch of the methods used in constructing our Western railways, and something of the circumstances surrounding the builders; not to give theoretical instruction, or to tell an unknown tale. The author has been for some twenty-five years in the midst of the fray, both as a pawn and as a player in the game, and the statements made are such as his experience warrants.

The lenses through which the critic views our railway systems and scans their details, can never be of sufficient power to reveal the barbed environments which circumscribed the actions of the time; nor can present analysis reveal the value, then placed upon fragments of time or upon small amounts of capital. To seize quickly the golden opportunity, and bind it with the slender means within quick grasp, lines with rich prizes at the yonder end were often cut! Uncaught fish are of little worth when the craft that floats us must be quickly handled or be wrecked. Yet a critic might declare, "A sad mistake was made right there."

MANNER OF GROWTH OF RAILWAY SYSTEMS.

No one of our great systems is the result of a carefully pre-arranged plan, but rather that of a welding together of numerous fragments, either ready made, or built as the plans developed and as seemed expedient to the management in temporary control; straight links, and crooked links, hooked together as they lay—'tis a wonder they are so good; 'tis a pity they are so bad. The rapid growth of plans, the whirl of events, and the tremendous energy displayed in wresting vast territories from wild nature, and from the other fellow, form a history of intense activity, which may be but outlined by the most masterly hand. The mainspring of all this energetic activity, was private gain, a feverish desire that the reaper should keep pace with the sower, as well as an ambition to lead in the race.

Corporations for any legitimate purpose are easily and cheaply formed, and often personal liability therein is too easily avoided. Before

* Manuscript received April 10, 1895.—*Secretary, Ass'n of Eng. Socs.*

the era of consolidated railway interests, railroad companies, some of village and some of national repute, were formed by hundreds, the latter to acquire some Government rewards, amounting in some cases to a score of thousands of acres of land and guaranteed interest upon a certain capitalization for each mile of railway built. Others availed themselves of state, county, municipal or private aid, either voluntarily offered by the people or diligently wheedled from them. While this aid, when honestly earned, has been usually a good investment for the donors, it accounts for many errors in location, of more or less importance, and for much seemingly extravagant economy in original outlay. In after years, when a furious race for supremacy came on, companies found themselves seriously hobbled by grades and detours unwisely introduced to secure some local aid. Still, many lines, of great importance now, could not have been built for many years without such help, and the policy, with all its evils, certainly accelerated the progress of development. The railroad syndicates very promptly formed land and town companies, which controlled the location of, and the title to, all new town-sites. Strangely (?) the original settlers were wonderfully unsuccessful in selecting just the proper site for a railway station, and villages seldom dared to refuse the required bonus "in compensation for the trouble incident to a station inconveniently located." Local aids were pledged to grade and tie the road; the right of way and grade was pledged to iron and equip it. Railway stocks went with the bonds as a make-weight; the acquired land grant was appraised low, railway stocks were sometimes made legal tender for lands, and the syndicate seldom happened to take the poorest lands in theirs. Thus sowers raced, and reapers trod their heels;—small wonder there was haste.

More recently, lines have been built to sell to one or the other company, many of them in the line of legitimate progress, but others vicious blackmailing schemes that blighted prosperity and retarded progress.

The larger extensions are now usually succored by some large corporation, or by individuals therein, having sufficient influence to secure their adoption by the company in good time. This is usually done with great secrecy, shrewd strategy and many denials. Local corporations of small pretensions are organized, by which contracts, and deeds for right of way are taken, and for which locations of line are more or less perfected; local rivalries are skillfully stimulated; men of local influence are flattered by official places; communities and individuals are caressingly milked quite dry of rights of way and privileges, and sometimes monetary gifts are made, although the latter practice is becoming of ill repute. When the scheme is ripe, a new company is organized, into which all local companies are merged, from which the now useless dignitaries of local repute are excluded, and by which, inconvenient pledges

made by these dignitaries are often ignored. The child is adopted by the parent company, either openly, as one of the family, or covertly, as a poor relation on probation.

Of course our railway managers are sometimes wonderfully far-sighted and keen in anticipating future exigencies, and in making all possible preparations for speedily capturing unoccupied territories in future years. Rival companies of gigantic resources hunger for the same game, when large enough to pot; and each watches the territory as does a hungry hawk the sward beneath. When the race for supremacy *does* come, mighty feats are done; each day new leagues are bound in iron bands, and Queen Silence is forever banished. To the intense excitement of such races, and to the desperation that seems to seize one or more of the rivals at witnessing the boldness and strength of the other, must be attributed many of the reckless entanglements of rival systems. It was a war between giants, and treasure was poured out with a lavishness that sorely challenged the reputation for sagacity that some of our strongest men had won before, and which arms the anti-corporation howler with powerful weapons of attack. But the sketch of conditions of growth is sufficiently amplified to furnish, to stranger and to critic, the key to many riddles.

CHIEF ENGINEER OF LOCATION.

Upon the chief engineer of location falls the burden of responsibility as to the possible economy of the line as it is developed under traffic, and yet he may not be permitted to locate it in accordance with his best judgment, for that judgment may be overruled arbitrarily by others, or by the force of circumstances, but such overruling leaves no trace of its action. To him also falls the personal supervision of the endless details of location. He either makes the original reconnoissance, or examines, at least, the best of the routes indicated by trusted assistants, and familiarizes himself with the general topography of the country and with such of its details as may affect the line chosen; as well as the resources of the country, the most promising town-sites, deposits of valuable material, the characteristics of the climate, soil, water, etc. In short, he must be authority upon all the questions which the fertile brains of the directors may concoct, and not unusually must he make a mental estimate of the cost of the road-bed, and of the time required for construction, in advance of any figures based upon measurements. It requires rare powers of quick and accurate observation, and of keen analysis, a retentive memory of locality, and sound judgment, to fill the bill. The quickly formed mental estimate of cost is often strangely near the truth; the skill to make it is a faculty highly cultivated in some, and never acquired by a dullard. He furnishes the field

engineer with general plans of all ordinary structures, with simple formulas for calculating the cost, or with memoranda of the same, as well as of the cost of grading, the maximum grades and curves permissible, the value to be placed upon distance, curvature and undulation saved; of permanent bridges eliminated, etc., etc. He inspects the line as laid, and the location and size of drainage structures, closely scans the cubical quantities calculated, fixes prices upon different portions, signs the preliminary estimates, and makes reports to directors. It is not unusual for an imperative demand to come for an estimate to be completed within two or three days, which, regularly calculated, would require as many weeks. "A special meeting of financiers must consider the scheme at an early date," or some such importunate circumstance seems always lying in wait to crowd the engineer. He must submit his best effort, upon which his reputation more or less depends, without show of hesitancy or discontent, or he incurs the odium of clogging the machinery by slow motion.

The problems incident to a scientifically adjusted location have been solved, upon the major portion of our railroads, largely by personal judgment alone, each engineer deciding for himself, by reasoning upon the particular case at hand, often with an acumen that bears the searching test afforded by unexpected volumes of traffic, and sometimes with the sole idea that a smooth light profile was the one supreme test of the ability of an engineer. The individuality of the locating engineer is traceable wherever he has worked. This applies the less, however, as the science advances, and as railway schemes are carried out with more deliberation. This fact is not surprising under the circumstances. Consider them!

Many of the most active locating engineers of former days, spent years at the front, rarely meeting a fellow craftsman or even seeing the work of other engineers; almost constantly remote from communication, and deprived of professional literature (aside from nature's volume and his own pocket note-books), with every day of his life crowded with pressing duties. A brief call upon his family, or from his wife, was the only shining light enjoyed during months of a life devoted to the stern demands of a calling arduous to the very extreme. Very eagerly have they drunk, upon opportunity, of the wisdom of others, but perforce they have been inventing methods, and gathering experience personally, striving, each to the best of his ability, to prove himself a man of superior ability in his profession. Indeed, the literature of this branch of the profession, at all applicable to practice under the conditions, has been extremely limited, until years subsequent to the growth of the greater portion of our railroad systems. Many of the conditions met and conquered by force of original good sense and judgment were never

met before, and still remain unrecorded. Many more or less arbitrary formulas, for calculating the alleged justifiable expense of eliminating a foot of distance or of undulation, or of a degree of curvature, have been used. Some of these are the result of elaborate calculations. They are useful, in comparing the values of different lines, as is a string of unknown length, in comparing unknown distances—but a railroad, located by the best formulas extant, might present many absurdities of great or small degree; for the simple reason that values of the same unit are not equal in different localities, even upon the same line or upon lines carrying the same traffic, even, possibly, within very short distances.

The following appears in the author's memoranda, as having been used by different engineers upon trunk line location:

TABLE USED IN EQUATING VALUES OF DISTANCE, CURVATURE AND UNDULATIONS ON THE *X* RAILWAY.

Upon ruling gradient of	Distance value, per foot.	Curvature, per degree.	Undulation, per foot.
0.4	$ 2 60	$10 00	$ 35 00
0.5	2 80	10 80	39 00
0.6	3 00	11 60	43 00
0.8	3 40	13 10	47 00
1.0	3 80	14 50	51 00
1.2	4 30	16 30	59 00
1.4	4 80	18 40	67 00
1.7	5 60	21 40	75 00
2.0	6 50	24 60	91 00
3.0	9 80	37 10	107 00
4.0	14 20	54 00	123 00

Distance value to be doubled for 5 or more miles saved. Table said to be for 100 trains per day, with coal at $12.00 per ton.

Upon *Y* railway.

Distance, per foot, $9.00.

For reduction of one degree in maximum curve per section of two miles, $2,000.00.

For reduction of curvature, per degree, $50.00.

For reduction of maximum grade per foot per mile, on divisions of 100 miles, $2,500.00. With maximum gradient fixed, reductions elsewhere, as above, $600.00 per foot per mile.

Upon *Z* railway.

Formulas for equation of curvature, where n = total number of degrees, and where d = degree of curve.

$$30\ (10 + \sqrt{n.\ d^3}) = \text{value of entire curve, in dollars.}$$

These will serve to illustrate different approaches towards the truth.

A reduction of the maximum gradient, to compensate for curve resistance, was formerly overlooked upon many lines, as were spiral approaches to curves, until still more recently. The use of both now prevails.

As to grade reduction, practice has varied as follows:

(1) For 1° curve 0.03 ft. per 100 ft., increasing to 0.05 for a 3° curve.

(2) For grades up to 0.7 per cent., 0.06 ft. per 100 ft.; for grades from 0.7 per cent. to 1.4 per cent., 0.05 ft. per 100 ft.; for grades above 1.4 per cent., 0.04 per 100 ft.

(3) For maximum grades under 1.5 per cent., 0.05 ft. per 100 ft.

(4) For maximum grades up to 4 per cent., 0.03 ft. per 100 ft.

Nos. 3 and 4 indicate the allowance now usual for prairie and mountain lines respectively.

Surveying parties number from twelve to sixteen men, including the engineer in charge. They are usually composed of bright, energetic and ambitious youths, who work from dawn until dark, and accept their rough camp life and untoward hardships, or perilous situations, with great good humor and with unquenchable spirits.

The locating engineer must be untiring in his diligence; up first in the morning, and often working hours after all others rest, regardless of poor candle light, plaguing insects, and other ills of life. He scouts the country in advance, weighing in his mind the various assortments of difficulties to be overcome, measures with his eye and compares horizontal and vertical distances, and directs all movements of his party. To attain marked success, he must be quick and accurate in judgment, unfatiguing in exertion, a leader of his men in all situations, commanding the esteem and personal allegiance of his party, and an excellent judge of country. The skill acquired by some in the last particular is marvelous. Usually the locating engineer runs the first line from a summit down hill, supporting an imaginary grade line by eye alone, and then corrects this line in projecting the line of continuous survey. In an accustomed country, with gradients from two to four miles in length, he should rarely misjudge the cut or fill at any point more than a few feet, and many times corrections are unnecessary, save for more carefully considered alignment.

Fully as great ability is required in the rougher prairie land as in the Rocky Mountains, as the limiting elements of the line are in a corresponding ratio with the difficulties met, and the calls upon judgment in choosing between numerous variations of alignment are far greater on the prairies. In the mountains, the gradient contour must be followed

(approximately) from top to bottom by purely instrumental methods, as any slight change of the conditions, such, for example, as the minimum radius, or equation for curvature, will, within a few miles, change the length of line, and consequently the elevation of grade line, sufficiently to require an entirely different development. The process is here mechanical, although requiring an adjustment of line to inches, in lieu of feet, in the flatter countries. Much of the mountain practice seemingly indicates that the engineer's formulas and study were directed towards eliminating tangent. The minimum radius was first established by test as to the sharpest curve the locomotives on hand could crawl around, and the gradients were established by the average fall of the stream followed, providing the locomotives could move themselves, plus something, thereon; and the first cost was reduced to the lowest, regardless of curvature. This may appear anything but skillful engineering, but financiers were rare that had nerve to invest in schemes considered so hazardous, and dollars had to be expanded, not expended. Without skill in expanding dollars, treasures inconceivable would still be untouched. The cost of location per mile varies extremely with the obstructions met and with the skill of the engineer in charge; and a variation of 100 per cent. in the progress made, and attributable to difference of skill and energy alone, as between engineers, is not unusual.

In undulating, partly timbered countries, 4 miles of closely laid preliminary is considered a good average daily progress, costing some 8 or $10 per mile. In open, flat countries, good work may be done at the rate of 1 to 1½ miles per hour. The cost of final location, including the preliminaries, upon the particular route selected, varies from about $40.00 per mile in undulating countries, to fully $2,000 per mile in the high mountains.

Where slopes are easy, contours are usually sketched by the hand level and pacing; in the mountains, by aid of center line profile, hand level and tape. The linked chain is pretty well superseded by the steel ribbon. Alignment work is occasionally checked by reference to the meridian, and errors of a few minutes are ignored. Levels are checked by repetition, and a variation of 0.2 foot in any one mile is often ignored, although location levels are usually much closer. Skillful instrument men are common, but extreme accuracy is too costly. The decimally divided foot, 100-foot stations, designation of curves by central angle for chord of 100 feet, the transit, the wye level, non-inverting lenses, and self-reading levelling rods, are used almost universally. Upon location, the station elevations are often taken to the nearest 0.05 foot upon a peg driven at the exact station and level with the surface.

Construction is usually entered upon suddenly, and pushed with an energy that is insatiable in its demands for *more* work and *less* time.

The engineer that has the start of a well-considered location line, before construction begins, is very fortunate. Location, construction and finishing grade stakes may all be urgently demanded of an engineer in a single day's work. Even when the chief engineer may know, for days ahead, that construction is to be crowded, he is liable to be restrained from the slightest move towards organizing his department, or from indicating in any manner a possible change in the situation until the time is ripe. Premature publicity would often be a great misfortune, and very rarely does an engineer enjoy the felicity of well-matured plans completed, and earthwork staked out, in readiness for a rush. When the time comes for action, then is the good metal in him tested. Presidents, superintendents, purchasing agents, right-of-way men, contractors, land owners, village delegations, patent-right men, newspaper men—and who not?—all heap work upon him in avalanches, or clamor for information and data regarding everything which their fertile brains can imagine may some time be wanted. Everybody, seemingly, intends to saddle him with any possible delay that may occur. Meanwhile, he must gather, it may be, scores of assistants from hither and yon, many of them strangers, size them up in a brief interview, assign them work, furnish them everything needful in plans, instructions, etc., and see that each takes hold of his portion satisfactorily. It is red hot work, but gloriously exciting, this concentration of weeks of vivid life into days! Were there not hosts of intelligent, energetic, honest men, trained to push in any gear, loyal to the company that pays them and to the chief that commands their respect, the organization and placing of a force upon some hundreds of miles in a fortnight, under such circumstances, would be well nigh impossible. The organization of the construction corps varies with circumstances and with personal ideas. A large undertaking is usually divided into portions of some 50 or 60 miles, each in charge of a resident engineer, whose charge is subdivided into divisions of a few miles, and a group of three or four men is assigned to each, under his immediate control. The chief holds the resident responsible for the proper execution of the work, and looks to him for constant information as to details, daily reports of all forces employed, monthly estimates and progress profiles, etc., as well as advice as to men and methods. In short, the resident engineer carries so much of the responsibility as his chief sees fit to intrust to him. The division engineers lay out the work, make all measurements, and work under specific orders in everything. The chief issues all plans and specifications, signs and interprets contracts, orders materials, has more or less control of right-of-way matters, makes monthly estimates of work done and materials furnished; arbitrates in complaints and disputes, numberless and annoying; makes reports upon endless matters, spurs everybody, and is supposed to see

everything, know everything, shoulder all mistakes, and please everybody.

The cost of superintendence varies almost directly with the number of details to be looked after, ranging probably between $20 and $50 per mile per month, including office expenses and salary of special corps in charge of important bridges, etc.

The right-of-way limits are generally defined by lines parallel with the center line and at a given distance from it. A strip 50 feet wide upon each side has become a standard width in most of the Western states, and is so recognized by the courts. It is often narrowed to exclude costly property, sometimes at great future cost. In such cases the chief engineer gives the narrowest limits practicable for present use. He also calculates the extra widths necessary on account of the nature of the work. Condemnation proceedings, under the act of eminent domain of the state, for public use, vary in the several states. In some of them, some kinds of property are not subject to condemnation. Usually, good reasons for acquiring widths above the standard are required in such proceedings, which give only an easement for railroad purposes, the title reverting to the original owner upon abandonment of the property. Titles in "fee simple" are acquired only by private purchase, are not generally taken, but are especially preferable in towns and cities, and, generally, in all cases. The government grants a strip 200 feet in width across its lands. The engineer furnishes the right-of-way department with maps showing all lines of government surveys, the numbers of townships, ranges, and sections, divided into forty (40) acre tracts, property lines, adjacent improvements, road-ways and the required right-of-way, and writes descriptions of irregularly shaped pieces required. Good practice fixes all right-of-way corners upon lines easily re-established from lines of government or city surveys, instead of at right angles to the center line opposite some station of the original survey, as is commonly done. It also acquires isolated bits of estate in the first instance; as reasonably convenient access to all property and to the highway is every man's right, regardless of cost to the railway company. No contract for a certain kind of crossing, or other unusual agreement, should be made without the consent of the engineer.

Contracts are usually let by competition between invited bidders. The amount of work, the ability of contractors, and other like circumstances, control the size of the contracts. Principal contractors are usually men of integrity, financial standing, immense energy and executive ability, and are often better practical engineers than the men in charge. They usually have in direct control sufficient teams, tools and men, to execute the more difficult portions, or those that for any reason drag behind, with an expedition that is at once an example and a warn-

ing to sub-contractors. They also have a large contingent force of sub-contractors, boarding bosses, overseers, etc., each with an outfit, small or great, and each more or less expert in special classes of work. These men habitually live in tents or shanties, constantly moving from one work to another, often hundreds of miles between, with fortunes constantly varying, but with a marvelous pluck that always has bright hopes for the next job. To their energy and pluck are largely due the many great achievements in their line. The great variety of soils, with their peculiarities under different conditions of weather and relative position, require of the successful railway builder a large fund of practical information, drawn from close and extensive observation, which cannot be acquired except by experience.

Western contractors lead the world in the use of the best appliances for the work in hand, and, as a class, deserve great honor for their achievements. Single-track, standard-gage road-beds, upon embankments, are usually from 12 to 15 feet in width, in earth excavations from 20 to 22 feet. Embankment slopes, 1 vertical upon $1\frac{1}{2}$ horizontal, are almost universally used, blindly so, for high fillings, as neither sand nor the ordinary soils will stand at this slope. Slopes of 1 in $1\frac{3}{4}$ have grassed over permanently, where adjacent slopes of 1 in $1\frac{1}{2}$ gave much trouble and expense. For cuttings, various ratios of slopes find defenders. In ordinary clays 1 in $1\frac{1}{2}$ is prevalent on new work, but they are often made steeper to save time or from mistakes as to economy, as material is generally removed from the side ditches by train in the form of mud until the top width of the cutting corresponds to that given by slopes of 1 in 2, or flatter. Material alongside a railway assumes flatter slopes than seem natural elsewhere.

The cost of earthwork varies considerably with surrounding circumstances. Grading of from about 1 to 4 feet in depth may sometimes be done for 8 cents per cubic yard. The prices to railway companies upon large contracts range from 12 to 18 cents per cubic yard for earth, 35 to 45 cents for loose rock, and 65 to 95 cents for solid rock. These are averages for the greater portion of the work done. The prices include a haul of from 200 to 500 feet, where necessary, above which 1 cent per cubic yard per 100 feet is usually paid additionally. This is usually calculated upon the whole number of cubic yards, multiplied by the distance between centers of gravity, less the free haul. Elaborate methods of calculation have not found general favor. The prismoidal formula is generally applied to calculations of earthwork by means of tables, although the cross-sections may have been carelessly taken, and deductions, on account of rounding slopes or narrow widths, may be *guessed* at the same time. More careful measurements of contents, and calculations by end areas alone, are practices which engineers graduate into by experience.

An allowance of from one-twentieth to one-tenth the height of scraper fillings is a common allowance for settlement, from one-tenth to one-eighth for wagon work, and upon wheelbarrow and grading-machine work, all one's conscience and the circumstances will permit. These allowances should be reduced under many conditions of time and weather during construction. The practice of measuring in excavation only does not prevail. The usual practice is to calculate center line quantities as per cross-sections, and the major quantity, whether in excavation or embankment, is paid for.

Classification of material is the engineer's *bete noire*, and the almost universal bone of contention between contractors and engineers. Some roads have thoroughly tried six or eight classifications in a vain attempt to eliminate disagreements, and have abandoned them for three only, viz.: earth, loose rock, solid rock. Definitions of these materials vary, but vexation of spirit is the shadow that always follows the responsibility of classification.

Wooden culverts are, of necessity, in common use, and, as usually built, are consistent with good (but not permanent) construction. Under low embankments with ordinarily good construction they are not objectionable when not too old, and, if properly cared for, they never fall down, and seldom wash out if nearly large enough. Good practice frequently permits their use under heavy embankments, but demands sufficient size to permit of the insertion of enough iron or other pipe for permanent use. This may require as much timber as would an open trestle for the same place, but it frequently admits of depositing large quantities of earth in permanent embankments, instead of wasting it, or it may prevent delay. Otherwise, open trestles are usually preferred, as being cheaper than both culvert and embankment, and as admitting observation as to the necessary waterway. The western climate is as yet untrained to habits of uniform propriety. Pipes of iron, beton, or vitrified clay, are often used in first construction, if the condition of transportation permits, and commonly for renewals. Iron ranks as first-class work; the others may also, under proper conditions. Iron pipes, rejected from water-works' service for minor defects, are usually good enough.

Stone culverts are usually rectangular, of short span,—from 2 to 4 feet—single or double, built of rubble, either dry or in cement mortar, with flat covering stone, sometimes strengthened by the insertion of old track rails. Dry rubble walls are generally nearly as thick as they are high, and require better stone than is usually found at reasonable cost. When laid in cement, the following rule gives safe dimensions, viz: where h = height of opening, and s = span of same.

Top thickness of wall at end in feet $= 1.5 + \sqrt{\frac{s + h}{4}}$,

batter on back 1 in 6. Make wall at mid length ½ foot thicker for each 10 feet of filling over culvert. The walls are heavy, but our stone is generally small, and, if large stone is procurable, its specification would usually increase the cost more than the additional yards required for rubble work. The cost of such work is from \$3 to \$5 per cubic yard, depending largely upon that of transportation. There are thousands of miles without a stone structure.

Arched culverts of ten or more feet span, are occasionally used in permanent work, but ordinarily, proper foundations for such culverts are very costly, and streams of such size are very liable to carry highway bridges and other large drift at times, and this renders the use of such culverts of questionable wisdom. The formula:

$$\sqrt[3]{\text{acreage}^2} = \text{area of opening},$$

is used considerably for determining the necessary waterway. It is all right for the majority of cases in the flatter countries, but may give insufficient waterway if the waters collect suddenly, and this depends upon the more or less uniform length of the several head branches, the slopes, etc.

The construction of timber trestles and their necessity are too obvious to require dwelling upon. Formerly, mortice-and-tenon joints were used exclusively, but present practice is advancing to the use of drift bolts. Up to a height of about 16 feet, pile trestles are preferred, the height being usually limited by the quality of piles procurable. Excepting the removal of the bark, piles are driven in natural condition. Pile drivers usually have leads of about 40 feet, and the hammers weigh from 1,800 to 2,200 pounds. Horse-power is generally used. Two teams alternately raise the hammer by pulling straight away from the machine at the end of the fall rope. The usual penetration, in upland soils, is from 12 to 15 feet. The pile heads are usually banded, but the practice is not satisfactory. Wrapping with telegraph wire, tightly drawn, is more so, but the cast-iron follower is the best. It closely resembles the hammer in weight and shape, is somewhat concave on its lower side, and holds a piece of the pile head in its top, upon which the hammer falls. Its use expedites the work, and effectually prevents the brooming of the pile. Good piles seldom require iron shoes. When they do, iron straps, crossed on the pile tip and secured to the sides of the pile, are best. In soils filled with boulders, a dynamite cartridge, exploded in a drill hole some feet deep, where the pile should stand, would usually suffice to admit of sufficient penetration, when it would be impossible with the ground in its natural condition. A sharp point is usually detrimental. In quicksand, the water-jet system is the only one prov-

ing successful among the several tried, and it is entirely so. In using it, the settlement of the pile should be controlled, preventing the weight from resting upon the pile point until the pile is deep enough. Constant inspection of pile-driving can rarely be dispensed with. Formulas for the bearing power of piles in trestle work are of but little use. The variation in the adhesiveness of soils, under different conditions of saturation and as affected by vibration, renders nice calculations futile and absurd. Good practice will not allow the punishment of good timber, which is common under arbitrary rules. As long as the pile goes without marked change in penetration, or punishment, we drive it, but ordinarily, if the penetration of a good-sized pile gradually decreases to about 2 inches, under the full fall of the hammer, it is pounded enough. In ordinary upland soils the depth driven should be about 14 feet, in deep alluvial valley soils from 2 to 4 feet deeper. Probably 4 feet additional depth would warrant accepting one inch less penetration under the last blow. There is need of large experience and excellent judgment in driving piles. They are seldom straight, or of uniform size.

Conditions of "no brooming," "no spring," etc, theoretrically required, are never attained. The condition of the soil varies largely with the season, etc. For equal energy, the blow of a heavy hammer is more effectual than that of a light one.

Piles will at times settle after bearing traffic for a year or two, while under other conditions they will be firm when but slightly pounded in driving.

The usual price of piles lies between 35 and 50 cents per lineal foot of length as billed. Transportation, and the distribution and size of bridges, largely control the cost. Framed timber, in trestles, is paid for per 1,000 feet board measure, and from \$25.00 to \$35.00 per 1,000 feet are ordinary prices. The bolts, washers, etc., generally cost from 4 to 6 cents per pound. The quantities of timber and iron used may average about as follows, as the memorandum is reduced from a large number of bridges. Spans 16 feet, 4 piles to the bent:

Pile bridges, height from 2 to 22 feet (average about 12 feet).

Per span.	Piling	105	lineal feet.
" "	Framed timber . . .	2,038	feet B. M.
" "	Wrought iron . . .	107	pounds.
" "	Cast " . . .	153	"

Single-deck framed trestles, 16 to 35 feet high (average about 24 feet).

Per span.	Piling	83	lineal feet.
" "	Framed timber . . .	3,286	feet B. M.
" "	Wrought iron . . .	122	pounds.
" "	Cast " . . .	172	"

Two and three-decked trestles from 41 to 65 feet high (average about 48 feet).

Per span.	Piling	79	lineal feet.
" "	Framed timber . . .	5,024	feet B. M.
" "	Wrought iron . . .	143	pounds.
" "	Cast " . . .	268	"

The average percentage of cost was :

	First type.	Second type.	Third type.
Piles	38 per cent.	24 per cent.	17 per cent.
Timber	51 " "	66 " "	75 " "
Wrought iron	5 " "	5 " "	4 " "
Cast "	6 " "	5 " "	4 " "
Average cost per lineal foot .	$8.35	$10.30	$13.91.

Average prices: Piling, 48 cents; timber, $33.00; wrought iron, 6½ cents; cast iron, 5 cents.

Bridge work is generally done in great haste, as the material comes from great distances and over the newly-laid track, and a race between the bridge men and the track layers is the usual programme. Good management and first-rate workmanship are here especially conspicuous when they occur. To secure the latter, and for other reasons, timber is not usually accepted until it is properly placed in the structure and the whole structure is properly completed. For several reasons large margins of strength are provided.

The display of energetic action and extravagantly hasty work often culminates in the track-laying. Previous delays have to be made up, investors thirst for income. The forces employed are very large, delays are costly, and no single imperfection of grade seems important enough to hold the track. Grading contractors are often artful in avoiding the finishing touches. Track-laying bosses are adepts in swelling extra bills for delays, and, as a class, are aggressive crowders of the "small fry" in their way. Narrow, rough, unditched road-beds too frequently result, and costly material, easily damaged, is hastily thrown down in the vicinity where it belongs. Cross-ties are taken by the construction train to end of track, tumbled off and hauled ahead by teams. A long line is stretched 4 feet, or workman's boot-lengths, from the center, and the ties lined thereby at one end, the joint-ties being first spaced by measurement. The rails and fastenings are loaded on a low, strongly built push-car, with rollers at each corner, and this is hauled to the front by horses. Men pull out rails at each side at the same time, and drop them. They are held, by bars, nearly enough to gage, to hold the iron car up, and the car is shoved ahead another rail length, fastenings being dropped at proper intervals. Joint-splicers and spikers

follow; joints, centers and quarters are first spiked to gage—more or less carelessly; the expansion joints are regulated by bits of wood or iron wedges, and their regularity is immediately destroyed by the throwing of the track to line, or as nearly to line as may be guessed, after the preceding operations have knocked out the engineers' stakes. Surfacers and fillers follow the liners. The best material that is extremely handy is filled in, and often the destruction of the track promptly begins by drawing spikes to raise the track, etc., but it is finally yanked into respectable line and surface, pronounced splendid, and turned over to the operating department, which has a lively wrestle with settling banks, kinked rails, bad gage, mud ballast, etc. In this work each man has certain motions to make, and progress is rapid, and this fact covers a multitude of sins. Records of over eight miles per day during daylight have been made. Happily, the use of this rough process is becoming rare, as extensions are more deliberately constructed by large systems that propose to operate them, and as track is laid by company foremen, instead of by contract per mile. Still, these foremen are judged rather by the daily progress made than by the maintenance expenses following, and nicety is not indulged in to great extent. Track-laying machines, by which all the material is drawn from the front end of the front car of the construction train are used to some extent. The front car is pushed onto the last rail length laid, as soon as it is partially spiked. Their use does not allow of surfacing before the locomotive passes over the track, and usually only part of the ties are first put in place. The machines are extolled, or deprecated, in various degrees. With them progress is limited to about three miles per day. Contract prices for track-laying, filling and surfacing (the track material being provided in material yards), ranges from about $325 to about $500 per mile. Probably $300 per mile will about cover the actual cost of labor in a force laying two miles per day in open country.

From this outline of professional practice in the front ranks of scores of millions of struggling founders of a new civilization, preparing for them a way, do you gather that our ways are crude and our practice rude? They are not more so than the dictates of uncontrollable circumstances compel. Kid gloves and hair-splitting niceties have been eliminated, 'tis true, but brains and untiring energy and physical powers have won the race. In the mighty rush of events which constitutes our domestic history, the coming of the railway engineer has been the first omen of the incoming tides of people, the first signal that a new channel for the bounding pulses of a young athletic nation was to be carved. His indomitable energy has made easy of access boundless treasures of wealth, locked in solitude since time began. Before him traditional deserts have vanished and bountiful harvests have followed closely

behind. From his footprints bright visions of fond hopes realized have ever blossomed. New-found homes for eager multitudes have sprung into beauty along his path, and eager thousands have quickly clustered around the centers which his keen foresight has first discerned and marked.

Nor has his pace been slow! Eight times in a century would it tame a wilderness of the combined areas of Great Britain, Ireland, France, Switzerland, Austria, Prussia, Spain, Portugal, Italy and Egypt. The swiftest denizens of our plains have been surrounded, and fields of grain have hidden the trail of the savage before he found a refuge. The restless, wiry "peg sticker" of our times has been a "potent simple" in the magical charm which has won the world's brightest land of promise from an obscurity as deep as time has been long. He has been here! he is gone, and is well nigh forgotten, but Chicago and scores of fair cities and immense regions filled with homes of comfort, bedeck his pioneer way.

ON THE BEST ARRANGEMENT OF LONGITUDINAL BRACING FOR TIMBER TRESTLES.

By M. E. Yeatman, Member of the Association of Engineers of Virginia.

[Read November 10, 1894.*]

Figs. 1 and 2 show the standard form of timber trestle work in use by the Norfolk and Western Railroad. In its general features this standard has been in use for many years, but it has been subject to such modifications as have been found desirable from time to time, either in the way of increasing the strength to correspond with the gradually increased weights of rolling stock, or of making such changes of detail as the practical experience of those concerned with the maintenance and renewal of these structures has suggested as likely to increase their durability or facilitate the necessary renewals. Under the first head, the size of the stringers, spur braces and longitudinals has been increased; under the last, the divided sill of two pieces, 6x12, instead of one 12x12, has been adopted, as these can be replaced without the necessity of either cutting off the tenons on the posts or raising the trestle bodily the depth of these tenons, as must be done with posts mortised into a solid sill.

Among such suggestions for improvement one has been received relating to the arrangment of the longitudinal bracing, and proposing to place this upon the outside line of inclined or batter posts, rather than upon the second line from the outside, as shown by the present plan. The present paper embodies an attempt to determine, from theoretical considerations, whether such a change would be an improvement or the reverse.

Let us for a moment trace the functions of the different members of the structure:

The vertical posts carry the loads, and the stringers are proportioned to the bending action of loads supported between the posts. These parts are essential in all cases. Then, to resist the transvere action of wind, or of centrifugal force on a curve, we have the inclined or batter posts, and these, with the caps and sills to hold them together, form all that is absolutely necessary in trestles of small height. It is usual, however, in all but very low trestles, to add face bracing or X bracing on each bent to secure the trestles from rocking sideways in the mortises as they would otherwise be liable to do, owing to the small inclination of the batter posts; and also to provide longitudinal bracing to resist the

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longitudinal force arising from the acceleration or retardation of trains on the trestle, for which we should otherwise have to depend on the continuity of the stringers, and on the end sill as an anchorage. As this end sill merely rests on the bank and has no great weight on it, such longitudinal bracing is generally required, but its function, in single-story trestles, is merely to keep the bents upright, and it does not seem to be a matter of much moment whether it be attached to the vertical or to the inclined posts, since the point which it will secure at the top of the trestle is nearly the same in either case. On the whole, as the vertical posts may be supposed to carry the heaviest load, they probably afford the best fixed point at the bottom from which to brace; and the braces will be also of slightly less length if used in the vertical plane; but this latter difference is very small.

When we come to consider trestles of a much greater height, an entirely new set of circumstances arises, for now the vertical and inclined legs are too long to be cut from single timbers, and, if so cut, they would be deficient in rigidity, under compression, unless greatly increased in cross-section. They are therefore made in lengths of from 20 to 25 feet, abutting against one another, but practically offering the conditions of two or more rigid pieces connected by joints hinged in all directions. It therefore becomes necessary, for stability, that each joint be fixed in place, this condition being secured if the joint be held firmly against motion in two directions at right angles to one another. This must be effected by proper systems of transverse and longitudinal bracing.

The transverse bracing is comparatively simple, since it is necessarily applied to every bent and in each story. It must not have so steep an angle as to become ineffective, and it is for this reason that the top story is limited to 20 feet in height instead of 25, and when, in the lower stories, a single brace would become inconveniently long, two or more are used. It is immaterial to which particular points at the top of each story the bracing is carried, for, when any one or more points are duly fixed, the intermediate caps or horizontal walings afford a secure brace against any transverse motion of the remaining points.

The circumstances of the longitudinal bracing are different, for, in order to secure a similar fixing of every point against longitudinal motion, it would be necessary to apply bracing to every set of posts just as transversely it is applied to every bent. This would involve the use of a great number of long and heavy timbers, and it is not necessary; for if we fix a certain number of the points in each story, we can still rely on the intermediate caps to keep the others approximately in place. I say only approximately, for we are now depending on the stiffness of the transverse pieces against bending, and this is a different matter from their effectiveness as direct struts or ties.

In the one case we have their length practically unchangeable: in the other, not only a quite appreciable yielding to any external bending forces, but their liability to assume, by spontaneous warping, a curvature sufficient to throw the unbraced points visibly out of line. Granting then that some of the posts in each story must be left unbraced, and thereby liable to get slightly out of line, the practical question is: which of the posts can be so left with the least damaging results?

The plumb posts, as carrying the direct weight of the trains, are the most important, and it is assumed that bracing will be applied to them; but this alone is not sufficient for (1) although these two points be absolutely held in place, the others, in the same bent and at the same story, may be considerably thrown out by curvature of the intermediate caps (see Fig. 3); and (2) in a high trestle the distance between the two plumb posts is so small, as compared with the whole width, that a very minute displacement of either of these will cause (even without any curvature) a serious displacement of the outer posts unless some of these are separately braced (Fig. 4).

The present practice is to brace also the second line of batter posts, thus fixing the points O, O^1 and Q, Q^1 (Fig. 5) and leaving P, P^1 and R, R^1 liable to slight displacement.

The suggested change would be to transfer the bracing from Q and Q^1 to the outermost posts, thus fixing the points R, R^1, as well as O, O^1, and leaving liable to slight displacement P, P^1 and Q, Q^1 (Fig. 6). To compare the displacement, we will call the lengths OP, PQ, QR, x, a and b respectively. Of these, a and b are constant, while x varies with the height of the trestle above the story considered.

Now assume Case 1 (Fig. 5) in which the points O and Q, in one half of any given intermediate cap, are fixed, and let the displacements of P and R be called p_1 and r_1; and Case 2 (Fig. 6) in which O and R are fixed, and let the displacements of P and Q be called p_2 and q_2. In either case the amounts of these displacements are to be limited by an assumed maximum curvature whose radius is C. Then we have (approximately, so long as the radius C is large)

Case 1 (Fig. 5).	Case 2 (Fig. 6).
$p_1 = \dfrac{a\,x}{2C}$	$p_2 = \dfrac{(a+b)\,x}{2C}$
$r_1 = \dfrac{b\,(a+b+x)}{2C}$	$q_2 = \dfrac{(a+x)\,b}{2C}$

Now, since all these quantities are taken as positive, p_2 is always $> p_1$ and $r_1 > q_2$. Also, $p_2 > r_1$ if $(a+b)\,x > b\,(a+b+x)$, if $ax > (a+b)\,b$, or if $x > (a+b)\,\dfrac{b}{a}$.

This, then, is the condition which must be fulfilled in order that the proposed arrangement may allow a greater displacement at any one point than the present one, and it depends on the height of the trestle above the line of caps under consideration; for (calling this height H.) the lengths a and b are constant ($=62$ inches and 50 inches respectively in the plan shown) and x is $= \frac{5}{24} H - 105$ inches (the batter of the posts being $2\frac{1}{2}$ inches to 1 foot).

This makes the above condition

$$p_2 > r, \text{ if } x > \frac{112 \times 50''}{62} = \frac{2800}{31} = \text{about 90 inches}$$

$$\text{or } \frac{5}{24} H - 105 > 90 \text{ inches, or } H > \frac{24}{5} \times 195 \text{ inches or} > 78 \text{ feet.}$$

Thus, for all cases in which $H < 78$ feet, including all trestles of four stories or less, the proposed change would be an improvement, as judged by the criterion of the smallest displacement of the most unfavorable point.

We can, however, go a little further, and consider, not simply the relative amounts of such displacements due to a given amount of warping of the timbers, but the results thereof. For, as soon as any given joint is thrown out of line, there results a tendency to be forced further out, a tendency proportional to the amount of such initial displacement and also to the compressive strain on the leg in question. The horizontal resultants produce bending moments on the horizontal caps, and the relative amounts of these moments measure the relative danger of collapse in given cases.

Now the maximum sideways bending moment in Case 1 may occur either at Q or at P; and, if we put P, Q and R for the vertical loads at these points, these moments may be expressed by

$$Mq = k\, R r_1\, b = k^1 K\, b^2\, (a + b + x)$$

$$\text{and } Mp = k\, R r_1\, b\, \frac{x}{a + x} + K\, P p\, \frac{a\, x}{a + x}$$

$$= \frac{k^1}{a + x} \left(R\, b^2 x\, (a + b + x) + P\, a^2\, x^2\right)$$

in which k is a factor common to both expressions and depending on the assumed limiting curvature and on the length of the posts in each story, and $k^1 = \frac{k}{2\, C}$.

The values of P and of R cannot be exactly determined, since we have no means of finding the exact distribution of the load between the different posts, but it is reasonable to assume that the loads are proportional to the sectional areas of the posts, or as 10 : 12.

Assuming this, and using the values given above for a, b and x, we find that Mq or Mp is greater according as H is less or greater than 83 feet.

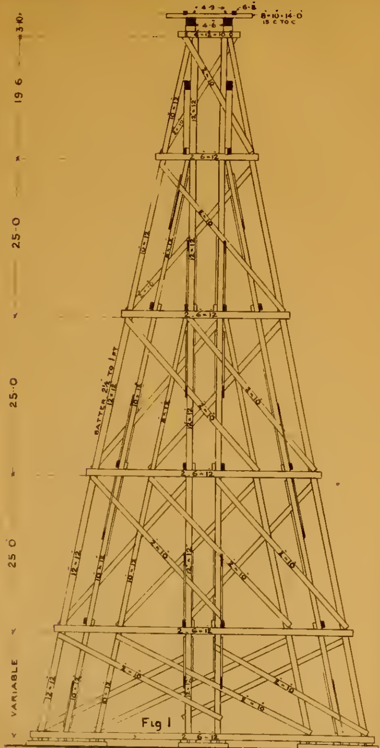


Fig 1

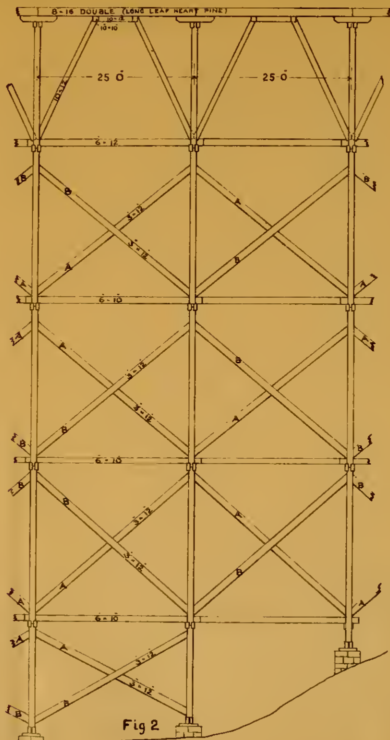


Fig 2

Fig 3

Fig. 4

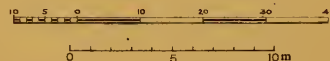
Fig 5

Fig. 6

LONGITUDINAL BRACING FOR TIMBER TRESTLES

BRACES MARKED A IN FIG 2 ATTACHED TO PLUMB POSTS, THOSE MARKED B TO BATTER POSTS

SCALE OF FEET



This shows us where to find the most unfavorable point in Case 1. In Case 2, for all trestles of considerable height, the point P will be the most unfavorable, and the corresponding moment M_2 will be expressed by

$$M_2 = kP\, p\, \frac{(a+b)\,x}{a+b+x} + k\, Q\, q_2\, \frac{b\,(a+x)}{a+b+x}\, \frac{x}{a+x}$$

$$= \frac{k'}{a+b+x} \left\{ P.\,(a+b)^2 x^2 + Q.\,(a+x)\, b^2 x \right\}.$$

Inserting the values of a, b and x, and making similar assumptions as to the values of P and Q, we find, on comparing M_2 with Mq, that M_2 is the less so long as $H < 80$ feet, but that, when $H > 80$ feet, M_2 becomes greater than Mq, and that, as Mp does not become greater than Mq until $H > 83$, Q is in Case 1 the critical point with which to make the comparison.

Our conclusion is, therefore, that for trestles in which $H. > 80$ feet, the proposed change would be an improvement, a result slightly more favorable to the change than our previous one, based on the displacements alone.

Now, in standard four-story trestles, $H = 70$ for the lowest line of intermediate caps (that is the height of the three upper stories is 70 feet, the bottom story being variable), and for all such trestles the change is shown to be an improvement.

For trestles of five stories, H would be 95 feet from the top of the bottom story, and in this case the change would be for the worse, so far as the bottom story is concerned, although for the better as regards the upper stories. But, of course, the bracing must be carried continuously down to the ground on any line of posts which is braced in the upper stories.

The following plan is therefore suggested for all trestles of two or more stories: Apply longitudinal bracing to the plumb posts and to the outside batter posts; and, in trestles of five or more stories, use, in addition, a set of bracing on the innermost batter posts of all stories below the fourth from the top.

This makes an improvement, at no additional expense, in trestles of two, three, or four stories, and, in trestles of five or more stories, it makes a great improvement in the lower stories (which are the most severely strained) by the addition of a set of longitudinal braces in one story of five-story trestles and in two of the stories of six-story trestles, and so on, if any of still more formidable height than 150 feet should be constructed.

The timber, in a trestle 120 feet high, would, by this change, be increased from 829 feet B. M. per lineal foot to 849 feet; and, in a trestle 150 feet high, from 1059 feet B. M. per lineal foot to 1099 feet, an increase of 2.4 and 3.8 per cent. respectively.

THE RELATION OF TECHNICAL TO LIBERAL EDUCATION.

By Dr. C. M. Woodward, Member of the Engineers' Club of St. Louis.

[Read November 21, 1894.*]

This discussion encounters two serious difficulties at the start: First, the definition of technical education; second, the definition of liberal education.

I. Etymologically, "technical" ought to include all arts as opposed to all sciences. But we all know that, beyond vague general suggestions, etymology is a very poor guide to exact meaning.

The Greek word *techne* suggests too much on the one hand and too little on the other. In the first place, we must omit all linguistic arts. Then, the trades are not "technical," as the word is used in this report. Iron-workers, wood-workers, cloth-workers, stone-cutters, leather-workers, glass-workers, and the like are not technical people.

"Technical" education always involves the application of the exact sciences to the arts of life, and every technical study needs the use of the higher mathematics, the principles of physics and mechanics and the aid of exact drawings. Thus, technical education belongs to the higher education. However, the fine arts of painting and sculpture are not usually included in technical education, though they lie very close to it, since they make careful study of form and of its representation, under the general heads of orthographic, isometric and perspective drawing. While technical education includes organic and inorganic chemistry, it does not include the preparation of drugs. It includes the general theories of ventilation and sanitation, but does not include the arts of nursing and healing. The arts of war on land and sea are highly technical, but in the United States these arts are taught by the general government exclusively, at Annapolis and West Point, so that they may be omitted from this discussion. None of us thinks of a naval or a military school when "technical" education is mentioned.

It thus appears that technical education is limited to substantially the following arts:

(1) Civil engineering, which deals with the construction of roads, streets and bridges; with geodesy, *i. e.*, the measurement of land and the making of maps; the construction of canals; the improvement of rivers and harbors; the building of dams, waterworks, reservoirs, sewers,

* Copy received March 30, 1895.—*Secretary, Ass'n of Eng. Socs.*

dikes, etc. This range is so vast and comprehensive that it has been subdivided many times, and one hears of hydraulic engineering, sanitary engineering, bridge engineering, geodetic engineering and of railroad engineering. The content of engineering is constantly increasing, as the exact methods of science replace the wasteful and clumsy methods of tradition.

(2) Mechanical engineering, which deals with the construction and erection of prime movers, such as water wheels of all kinds; steam, air and gas engines and windmills. Next, the immediate connections of these, such as pumps, fly-wheels, shafting, saw-mills, flour mills, rolling mills, elevators, hoists, furnaces, machines, and tools of all kinds, sizes and uses.

It is evident that the scope of mechanical engineering has widened rapidly ever since it adopted scientific methods and took on the dignity of a profession. People generally have a very inadequate notion of the functions of a mechanical engineer. To be sure, he knows the theory and uses of tools and the properties of materials, just as the graduate at West Point knows by actual practice how to handle a musket, how to pitch a tent, how to load a field piece and how to keep a camp clean; but when he is in the practice of his profession it is his function, as it is the function of an army officer, to plan and calculate, and to direct men. When the civil engineer, Monsieur Eifel, built his famous tower, does any one suppose that he put his hand to a single bar of steel as it entered into that elegant structure, which was as exactly calculated as are the motions of the moon? When Engineer Ferris erected his monster wheel, does any one suppose that he struck a single blow or lifted a single ounce of it with his own hand?

Please do not suppose that I am saying this for the purpose of showing how genteel a profession engineering is. I am concerned only with correctness of definition. A mechanical engineer is not an engine driver nor a machinist; any more than a city superintendent is a class-room teacher. An engineer, if properly trained, could "run" the engine, or handle a tool, as the superintendent could conduct a recitation, and do it extremely well, too, if there should be occasion, but that is not his business.

I hardly need add that there are many excellent workmen who are anxious to be considered engineers, in the sense in which I use the term, as a product of technical engineering education, but who lack the broad training which is strictly essential to such consideration.

(3) Electrical engineering, which includes the theory, science and art of construction, erection and maintenance of all the devices of dynamic electricity—generators, motors and the means of electrical transmission. This is the youngest of all the technical professions, and

yet it is one of the most difficult. The problems involved are among the most profound and intricate. Though dealing only with one form of energy, it already covers an immense field, and its boundary is receding rapidly on all sides. As you well know, there is an army of electrical workers, but the number of thoroughly trained electrical engineers is small. I doubt if there are 500 in the United States. The need of them is very great, for a great deal of our electrical work is very wasteful.

(4) Architecture, which includes the design and erection of buildings for all sorts of uses and of all sorts of materials. This is the oldest of the technical professions, but its modern developments make it almost new. So long as stone was the chief material used in buildings, and only churches and palaces were supposed to have any architecture, the problems of the architect were those of masonry and surface ornament; it was a question of columns, capitals, entablatures and arches. Modern architecture constructs with steel pillars, steel girders, steel trusses; and, though surface decoration (often of the most illogical sort) is introduced, the skill of the designer is largely spent on the details of plumbing, heating, ventilating, lighting and grouping. We insist to-day on having what the private citizens of Athens and Rome never had, homes of grace, comfort and convenience. The introduction of steel and glass and hoisting machinery demands new styles, new orders. The great need of architecture to-day is freedom. It must be liberated, set free, from the slavery of styles which were appropriate only to stone. We see the effects of this bondage in such incongruities as iron pillars that pretend to be blocks of stone, and a rigid frame of steel with a veneering of brick.

The coming architect of steel must be near at hand. Harvard recently gave an honorary degree to the man who designed the Masonic Temple of Chicago.

(5) Chemical engineering, which includes the departments of metallurgy, gas, the occurrence and the treatment of ores, minerals and clays, and the production of valuable compounds. It is evident that the chemical engineer is a factor of growing importance in every highly developed community. The energy, which appears under the two closely related forms of light and heat, is the special form which the chemical engineer employs, as the alchemist of old would have used the philosopher's stone, to transmute dross to gold. With these magic wands he unlocks the secret store of nature and increases the riches of the commonwealth.

It is evident that these various branches of engineering overlap each other at many points; for they form, not isolated areas, but the continuous and ever enlarging circle which bounds the domain of science and marks the conquest of human intelligence over the arcana of the material world—the victory of the known over the unknown.

There are other arts, like those of agriculture and horticulture, which, while embraced under the general term of biology, rest more or less upon the exact sciences, and hence admit of systematic presentation. They belong to the ground common to mechanical and chemical engineering. Farming is getting to be largely a matter of machinery, and the problems of soil, climate and plant culture are those of chemistry. The agricultural engineer has not yet been born. Farming is not yet a profession. It is rather a trade, with a maximum of art and labor and a minimum of science.

Again, usage puts into technical education far more than mere art, for every technical profession, properly so-called, is both a science and an art. Hence, all pure science is tributary to technical education, though, of course, not equally to all branches. A technical school is, first, scientific; and secondly, professional. The relation of applied science to pure science may be illustrated by the relation of Greek and Latin literature to the study of Greek and Latin Grammars. The eminent value of one is that it leads to the other. The Roman soldier was trained in the use of the spear, the shield and the short sword because he was expected to use them; the modern soldier expects to use repeating rifles and Gatling guns, and he is trained accordingly. Technical education is equally logical.

Finally, a "technical" course of study includes a great deal that is not technical at all, but which nevertheless must be taken into account when speaking of technical education.

Take, for instance, the technical courses in the Science of Engineering in Washington University. They are invariably four years long, with a possible fifth, or graduate year. Freshmen enter with a knowledge of algebra, plane and solid geometry, the elements of drawing, elementary physics or chemistry, American and English (or ancient) history, two or three years' work in Latin, German or French, and a passable knowledge of English.

The curricula are very similar to corresponding curricula in the Massachusetts Institute of Technology and Cornell University. From sixty to seventy per cent. of all such courses is found in the courses for bachelor's degree of all first class colleges, and in some, the proportion is still greater.

This common, non-technical material consists of modern languages, mathematics, mechanics, rhetoric, literature, physics, chemistry, geology, mineralogy, political economy, astronomy and elocution.

When a college is able to offer a large variety of electives they are more often taken from technical courses, though scarcely technical themselves, such as descriptive geometry, surveying, drawing, applied mechanics, theories of structures, electricity, and the like.

An examination of the last catalogue of Harvard shows that its course of instruction offered to the candidates for the degree of A. B. contains 87½ per cent. of our course in civil engineering, 75 per cent. of our course in mechanical, 94 per cent. of our course in electrical engineering, and 100 per cent. of our course in chemistry. In like manner our own A. B. course includes nearly all of our technical branches.

II. Thus far I have considered the limitations, and, again, the greater extensions of technical curricula. I have now to consider the character, meaning and content of "liberal education." Undoubtedly, it is a very loose term, and no two of us would wholly agree on its definition. Originally, a liberal education was that course of training which was befitting a freeman and a gentleman as contrasted with a slave's education to labor. The aim, to quote Webster, was "amusement, curiosity, intellectual improvement, rather than the necessity of subsistence." So long as direct utility was in view, it was not liberal. Education began to be liberal as soon as it got beyond the idea of immediate use. Hence, Lowell is said to have defined a university as a "place where nothing useful is taught."

I do not know in what connection Lowell uttered these words, but by "useful" he must have meant "directly and immediately useful for earning a living and limited to such use," otherwise the statement would be as ridiculous as it is extravagant. Is there anything in science, in art, in history or in literature, which, when thoroughly comprehended, has not a probable or a possible use? There are uses and uses; primary, secondary and ultimate uses; higher uses and lower uses; immediate and remote. The phrase "thoroughly comprehended" has a saving grace. It makes things useful which otherwise were useless. The most useless things in the whole world of education are things imperfectly learned; things taken up, then not mastered, but laid aside. Do we not tolerate too many of these useless things? So impressed am I with the utter worthlessness of much that is called "liberal" that I would define a true university as a "place where nothing useless is taught."

The word "liberal," in modern education, refers, not so much to the subjects studied, as to the method of studying them. The liberal method is broad, deep, generous, comprehensive. It is not limited to mere immediate use. It recognizes use only as the greater includes the less, but it is not limited to it. That thorough mastery of a subject which makes it available for all possible uses, necessarily includes the near as well as the remote. The liberal method aims at the artist rather than the artisan; at the engineer rather than the craftsman; at the head rather than the hands. Liberal culture deals with fundamental principles, typical phenomena; with general results, not special

applications. It is liberal to study, under the head of political economy, the laws of manufacture, trade, commerce, finance, supply and demand; it is not liberal to learn merely the conditions of a successful business in a given community at a given time.

The list of liberal branches is ever increasing. When I was at Harvard I was compelled to give one-sixth of my time to Greek and one fourth to Latin. I studied political economy for a single term. I never entered a laboratory except to sit down and listen. I did not do a stroke of drawing. I did not even know that there was a science as well as an art of drawing, and that its name was descriptive geometry —a sadly neglected study, which affords more mental discipline in a given time than any other study I know. I am glad to be able to testify that now, not only at Harvard, but at Washington University, and at scores of others, West and East, one may study Latin and Greek or not, as he chooses, and that everything in all sciences, arts and literatures admitting of systematic treatment, is offered freely to all who may choose, as a liberal course. People now study Greek and Anglo-Saxon, not because they are compelled to, but because they wish to, just as they may study mechanics or descriptive geometry or electricity, or thermodynamics. And they do not—or, at least, they should not—study them in any mean, superficial, perfunctory way, but broadly, comprehensively, with relish and enthusiasm. With such opportunities and by such methods all university work should be liberal, and all liberal work should be in the university. Do any suppose that our students are less liberally trained than formerly? The material of which college curricula are made has increased many fold since most of us took our degrees.

The adoption of these ideas has lifted, and is lifting, all the work to a new dignity. The college of letters is no longer a narrow school for the training of professional men.

Remembering the fact that, up to 1850, the purpose of our American colleges was to prepare men for the four professions of theology, law, medicine and teaching, we can see on what utilitarian lines the course of study was formed. The clergyman must read the New Testament in the original; the lawyer must read Cicero, Quintilian, and the "Institutes" of Justinian; the physician must read Galen, the professor must take Latin, Greek and mathematics. The plan was simple and reasonable.

Suddenly, a group of new professions appeared and struggled for recognition. The age demanded them, and it demanded, too, the introduction of new elements in education, just as liberal, just as closely touching life, society and progress, just as humanizing, just as logical in reference to the new demands, as the old elements had been in reference to the old demands.

A professional degree is a stamp placed upon the forehead of the graduate, declaring him worthy the confidence of those who may need the service of a doctor, or an engineer, or a lawyer. Before one can worthily receive such a stamp, he must be in possession, not only of a trained and vigorous mind, familiar with general laws, but of a large fund of exact information, much of which is matter of time and place.

Every technical course has more or less of this professional material, and just to that extent it differs from the highest type of liberal education. These facts of time and circumstance—dates, prices, statistics, etc.,—which to-day have value and to-morrow are ancient history, should ever be minimized in the presence of unchanging principles, general theories and inexorable laws.

It thus appears that, when we take into account the current meaning and the scope of technical education, and the full significance of liberal education, we find that nearly all of the ground is common, and that, even when the branches of study are different, the spirit and method are much the same.

I have had unusual opportunities to know what is meant by a high-grade technical course of training. I know how every subject is treated historically, empirically, experimentally and theoretically. Take the subject of bridges, and you will find that the evolution of the modern most finished types involves a history as long, an analysis as profound, and a variety as great as in the development of forms of government or of religious belief.

From stone arches, circular, segmental, elliptical and oblique, to tubular bridges, to truss bridges of many kinds, to steel and iron arches, to suspension bridges, and to the modern cantilever which spans 1,700 feet, is a very long story, full of the achievements of intellect, genius and daring. In the presence of such a history and exposition, a hundred matters, that men make much of in the records of human achievement, pale into insignificance. Before that history can be read intelligently, the laws that obtain in all operations involving force, motion, energy, mathematics and mechanics, must be so mastered that they are not a "memory and a forgetting," but are the keen-edged tools ready for use in a high analysis. He who reads aright the history of the great steel arch built over the Mississippi by Capt. James B. Eads at St. Louis, reads the history of a thousand bridges. Said one of the most highly cultivated men I have ever known: "To read the full history of such work is a liberal education."

I have mentioned but a single subject in the technical courses, and yet you see how far reaching it is, how closely it is connected with the development of our civilization, with the gradual mastery of mind over matter. When I first read Browning's pathetic little poem, "The

Grammarian's Funeral," I could not avoid the feeling that it was satirical. It was impossible for me to believe that he could sincerely admire one who had devoted so much of his life to the "business" of two Greek words of three letters each.

Accustomed as I was to an intellectual atmosphere where authority was at a minimum and where the conclusions of a sound logic were supreme, I could not bring myself to see either heroism or genius in an endless conning of texts and a grouping of passages. A better acquaintance with Browning, however, convinced me that the poem is the tribute of a sincere respect and admiration. I shall not quarrel with Browning. *De gustibus*, etc. I quarrel only with those who do not see the intellectual character, the dignity and the culture of the accomplished engineer; a man who has so thoroughly mastered the laws which govern the forces of nature that he is able to make them subservient to the needs, the comfort, the luxury, the refinement of our race.

It is very easy to see the sources of a widespread prejudice against technical training. The history of civilization has been the history of masters and slaves, of caste, of contempt for all labor and for all useful arts. No wonder that Plato held that the useful arts were degrading, for they brought one into the companionship of slaves, for even in Athens, every freeman lived in luxury on the labor of several slaves. Caste prejudices were equally strong in Milton's time in England, so that Milton places Memnon, the chief engineer and architect of the hosts of heaven, among the fallen angels. In spite of his energy, his knowledge of ores and their treatment, and his marvelous skill in construction,

> He was headlong hurled
> With his industrious crew to build in hell.

The technical professions are all less than one hundred years old. They are all evolutions from trades. The first mechanical engineers built their own engines, and the first electrical engineer built his own dynamo. There is, therefore, an odor of the shop about the names, and a reminiscence of men who were heretics as regards theory, but firm believers in practice.

We all know the intense squeamishness of the average college professor with regard to anything which savors of use. "Thank God, that department can never be made useful," said an eminent professor, speaking of a newly established chair in a State university.

A similar spirit would seem to have prompted Professor Patten, in an article on the "Educational Values of Studies" (see *Ed. Rev.*, Feb., 1891) to say that a study loses its educational value in proportion as its economic value increases. Hence, mathematics and electricity have less educational value now than when they were of less utility. This statement is so incredible that I give his exact words:

"With the increase in their utility they will be of less value in educating men. Whatever makes them more fitted for utility studies, makes them less fitted for general culture." Again, he asked: "Shall a subject be taught with a view of making the student a master of it, and thus enable him to obtain a utility (*sic*) from it? or shall it be taught with the purpose of producing the greatest effect upon the mind and culture of the pupil?" Professor Patten would have no objection to making a student a master of a subject, provided he were sure that the mastery could be of no use to him, for then he would be educating a man as man, and the result would be general culture. But let it be discovered that that mastery enables one to solve a practical problem, to earn a loaf of bread, or to make two blades of grass grow where one grew before, and lo! the man is less a man, the mental effort becomes narrow and undesirable, and what he fondly hoped was culture turns out to be mere "expertness" and "adroitness."

We have all met with similar arguments and prejudices, but one rarely comes across such a frank expression of them. Fallacies which have come to be hundreds of years old, die hard, and to some it is a species of educational blasphemy to call them in question. It is for this reason that the majority of readers probably accepted Professor Patten's statements as gospel truth.

But such a statement cannot be quietly passed in this discussion. The relation of technical to liberal is far more intimate and cordial than is commonly supposed. I assert with confidence, that whenever a mastery becomes technical through use it is still liberal and more nobly liberal, and that a study is useless in proportion as it fails of mastery. The introduction of technical subjects into elective courses usually called liberal, so well begun at Harvard and promptly followed in a dozen universities, has met with opposition on the ground that there is something in technical study, or in the atmosphere of a technical school, unsuited—or at least, less suited—to a proper discipline of the mind and unfavorable to the growth of character. Says Dr. Wm. M. Bryant (*American Journal of Education*, February, 1891): "The professional school necessarily directs the attention of the student mainly to success in its outward aspects. It is in the college proper, where studies are suited to discipline and develop a man as a man, that the conditions are most favorable for the growth of character."

The assertion that in technical study the attention is mainly directed to success in its outward aspects, is based on a misconception. Much is made of useful applications because they serve as illustrations of general principles. But the only "success" the student is conscious of, is the success of his effort to thoroughly understand the science involved and how it is applied. That consciousness "keeps his mind alert, expectant

and enthusiastic." The zeal of the technical student is akin to the zeal of the student engaged in research in the laboratory, and you know well what that is. It is as far as possible removed from the thought of "success in its outward aspects."

The belief shown by Messrs. Patten and Bryant is widespread, particularly among those who have had no direct contact with technical work. I have seen both kinds of training intimately. I have seen them in separate institutions, and I have seen them side by side in the same institution. So far as relates to vigor of intellect and high character, the influence of technical studies is in no respect inferior to that of the traditional untechnical curriculum. On the contrary (and I am not alone in this opinion), there is a widespread and uniform degree of earnestness and zeal among technical students, rarely equaled in colleges which do not admit technical branches. The sense of responsibility, which accompanies the study of subjects which cannot be slighted without leaving a defective foundation on which to build later, is helpful to serious and steady work. On the other hand, I remember that, in my own college days, it was difficult to look upon much of the college work with any considerable degree of earnestness. It seems to be irrelevant. The idea of thoroughly mastering a subject so that one could base something else upon it, rarely entered the head of the average student. I recently met a college classmate as an officer in a technical school. We fell into conversation as regards the influence of technical study on the development of character. Said he: "The earnestness and manliness of these students has been a revelation to me. There was nothing like this when we were at Harvard."

I shall be very glad to hear what has been the effect of the introduction of technical studies at Harvard; what proportion of the senior elections are what are called technical, and what influence they have had on the character and scholarship of the seniors electing them.

The character and attitude of the educated engineer towards classical learning, has much to do with the estimation in which he is held by scholarly men.

The engineer is by nature an iconoclast. He has small respect for the traditions. He snaps his fingers in scorn at all whose chief pride and glory lies in their submission to the "tyranny of the ancients." He cares less for what has been than for what may be. His triumphs, his masterpieces, his heroes, his golden age, are all in the future. He walks forward, with his face to the front; not backward, with his face to the past. When Captain Eads proposed to build a steel arch over the turbulent Mississippi with a clear span of 520 feet, the timid worshipers of the past held up their hands in protest that there was no precedent for an arch of such great length. To this unworthy opposition

it was said proudly in reply: "The engineer makes precedents; other men follow them."

There is another aspect of the effects of our modern liberal technical training, which is somewhat new. In that graceful liberal culture, which we all so much prize and which we more or less unconsciously set up as a standard for others, we learned how the imaginative Greeks made gods and demi-gods to account for wonderful things. Beings with superhuman strength and skill turned the courses of rivers, built impregnable walls, bore messages faster than the wind, and subdued monsters, drained marshes and warded off disease. Not to know these things is now held to be wanting in the very elements of a liberal education. In these modern days, men have done all these things and more, in fact and not in fancy, and yet to know these modern heroes—men, accomplished, but in no way superhuman—who have dethroned the gods and put demi-gods to the blush, is held to be not liberal, and such knowledge exposes one to the suspicion of being too familiar with swarthy fellows who handle machinery and despise the ancients. Men are now struck dead by artificial lightning, while the thunderbolts of Jove are turned harmlessly into the earth by a Franklin, and the energy of which thunderbolts are made is harnessed to a car or a mill by an Adams or a Hopkinson or an Edison, and made to serve the peaceful ends of commerce and industry. The dreadful energy of a Maxim gun or of a dynamite cannon is far more destructive than the twanging of Apollo's silver bow and his whole quiver of arrows. The skill of an Eads, which turns the current of the mighty Mississippi and forces it to maintain a new deep channel into the sea, dwarfs into insignificance the labors of a Hercules. The ingenuity of a Morse and a Field sends messages to the antipodes in less time than Mercury needed for binding on his sandals. The roar of Mars could be heard by whole armies; now the whisper of a Brush is heard a thousand miles.

It is now the engineer who turns away the destroying monster, redeems the waste places, brings health, peace and security where there was pestilence and death. Shall not an accurate knowledge of the exploits and rational methods of these modern times and heroes be held to be an essential part of a liberal as well as of a technical education?

Is not the educational army changing front? Is not our new leader an engineer, rather than a philologist or an antiquary? We all believe in culture. The word is much abused; perhaps I have helped abuse it; but there is culture and culture. Whatever broadens one's intellectual grasp, extends his mental vision, purifies his mental taste, lifts him away from individuals to generals, builds rational ideals, is an aid to culture, and, *ipso facto*, is liberal. This high function I see in high-grade

technical education. I urge most earnestly that, as is done in many universities to-day, on the one hand, all narrow, petty, ephemeral matters, which have no logical bearing upon life, be eliminated, and that technical subjects in their most liberal form be incorporated into the college course as possible electives. No longer should it be true anywhere, as, according to the Emperor William, it is now true in Germany, that they have an overproduction of what are called "over-cultivated men," who, instead of being an element of strength to the State, are a source of weakness, being unfitted for life and its problems. The college student should have free access to all subjects liberally taught, which he may choose according to the quality of his mind or the promptings of his future.

To this end technical and liberal departments should be brought nearer together and unified as much as possible. The wall of separation should be thrown down.

The relation between technical and liberal education should be that of the French motto: "Liberty, Fraternity, Equality."

THE MANUFACTURE OF CEMENT FROM FURNACE SLAG.

By Hermann Crueger, Member of the Association of Engineers of Virginia.

[Read March 28, 1895.*]

The question as to what should be done with the refuse of manufactories of all kinds, is one which for a long time has agitated the minds of the most eminent chemists as well as those of practical men, and is one of ever-growing importance. After use has been made of raw materials, the refuse is again turned into a raw material, the uses of which, after many years of trials and experiments, have in some instances exceeded in value those of the original product from which these raw materials were obtained. I need only call attention to the uses now made of gas coal tar, a product which, not so very long ago, was looked upon as entirely a secondary matter, and, perhaps, used only for preserving wood from decay. Aniline dyes, and other chemicals largely used for medicinal purposes, etc., etc., are now produced from it.

Cotton seed affords another well-known instance of how a substance which at one time was considered almost worthless has proven to be almost as valuable as the cotton itself. Quite a number of other products are now being utilized.

Furnace slag (in German Hochofenschlacke) has always been a source of trouble to furnace men, and I well remember the expression of an old friend of mine, who claimed that the location of a furnace should be chosen at a point where the disposal of the slag would be attended by the least possible trouble. Of late, furnace slag, where it can be had cheaply, is being used in ballasting the road-beds of railroads; and since the question of better roads has been agitated furnace slag is being used quite largely for road improvement; but the amount used is very small in comparison with the amount of slag produced. For a number of years experiments have been carried on, particularly in Germany, Switzerland and France, regarding the practicability of manufacturing an hydraulic cement from slag, and, after a number of failures, these have proven successful, particularly where improved machinery adapted to the work has been used.

To a large extent I am indebted, for the information on the subject of this paper, to Professor Tetmajer, of the Polytechnic School of Zürich, Switzerland, who has made this particular matter his study and embod-

* Manuscript received April 22, 1895.—*Secretary, Ass'n of Eng. Socs.*

ied it in his admirable pamphlet entitled "Furnace Slag Cement," mentioned in *Engineering News*, of July, 1889, since which time I have given this subject attention and have obtained, from various sources, information convincing me that the manufacture of hydraulic cement from furnace slag in the United States would prove to be not only practicable but profitable, if properly conducted.

The uses to which cement is now being put are daily increasing in number, including concrete walks, concrete in fire-proof buildings, concrete for brick-paved streets, etc., etc., and there is no reason why cement, if manufactured cheaply, should not, in course of time, almost entirely supplant lime for building purposes.

From Prof. Tetmajer's pamphlet, above mentioned, I beg to quote the following extracts:

"The first attempts to make slag cement by machinery were made in 1879–80, at Chomdez, Switzerland. In addition to slag bricks made, ground slag was produced and was called trass. It appeared at the Swiss Exposition, where it attracted general attention from experts. Slag cements have been introduced mostly by the founders of the Slag Cement factory at Thale, by Mr. Boss, architect, Brunswick, and by Mr. Hermann, manufacturer of cement, at Thale.

"Every normal slag cement is made of granulated furnace slag, ground to a condition of dust, and of calcium hydrate in the form of powder. According to local conditions, there can be added to the slag-lime mixture further artificial or natural pozzuolanas, silicates, silicious or silico-alumina preparations.

Furnace slags are principally lime and alumina silicates, made as secondary products in smelting iron ore. The chemical composition and the chemico-physical condition of furnace slags vary with the proportions of the ore, fuel and fluxes, and with the smelting temperature. In general, we distinguish acid, neutral and basic furnace slags. The slag is called acid whenever an equivalent of acid contents contains less than an equivalent of the base. In the opposite case, slags are basic. The neutral slags are those intermediate products which are found only in exceptional cases. Acid slags are used principally in the making of slag bricks and in the preparation of road materials. Cooled in water, they furnish a so-called slag-sand, which is used for road-making and in making mortar. By blowing slag with steam, slag-wool, or mineral wool, is made. Since it has become possible to de-sulphurize slags, it has also been used in the ce nent, glass and pottery industries.

"The sand made by granulating basic slags, works as an hydraulic addition when mixed with slacked lime or powdered lime hydrate. Pressed into moulds, it furnishes bricks for surface construction, or for works under water.

"It has long been known that certain kinds of basic furnace slag, granulated and mixed with lime, acquire the property of hardening hydraulically. The nature of the effect of granulation is now beyond question. It was formerly supposed that granulation effected a partial molecular change, which might be called a decomposition of the slag; but furnace slags are not silicates in the ordinary chemical acceptance of the term. They are complex alloys which are decomposed when made fluid by steam or a strong current of water. Slag loses a small part of its sulphur and silica, and probably other matters are set free. These can, by taking up water, combine with lime and consequently harden. Treated with hydrochloric acid, granulated as well as ungranulated slags become gelatinous, the granulated more energetically than the others.

"According to its chemical composition, basic slag which has been properly granulated presents a varying appearance. The particles of sand resemble weathered granite. In this case the particles are mostly round and translucent. Some, however, are not translucent, and others resemble pumice. The surface of the grain is generally lustreless, sharp like quartz, although less sharp than the sand of granulated acid slag, which latter is in pumice-like pieces, having the characteristic glassy lustre. Other less valuable slags show, when granulated, a slightly glassy, earthy, dirty lustre. The color of slag-sand is generally grayish. Slag made while the furnace is in good heat is slightly violet, and, when ground up, reddish.

"Granulation, and with it the degree of usefulness, varies considerably. The less the pressure and the temperature of the slag and the warmer the water, the smaller becomes the chemico-physical effect of granulation. White, hot, thin (highly fluid) slag, leaving the furnace at a high pressure, is particularly fit for granulation; slags made from gray foundry iron, allowed to accumulate in the furnace and conse quently tapped under high pressure, give the best results.

"The slag spout should be as short as possible, and the stream of water strong. The same slag, differently treated, gives a valuable slag sand, according as the slag is granulated when very fluid or when in a syrupy condition. Slag about to chill furnishes less valuable material and is similar to the sand made from a cold slag.

"Every basic slag has a certain lime limit within which it will preserve its shape as commonly cooled, and above which it will disintegrate. The slag dust made from slag in the latter condition is valueless for cement mortar, as shown by various experiments. The degree of effectiveness of a furnace slag depends chiefly on the proportion of lime to silica. Slags in which the proportion $\frac{Ca\ O}{Si\ O_2}$ (lime to silica) sinks

to about 1.0, cannot be used for the making of slag cement. Under otherwise similar conditions, the lime capacity of a slag increases with the growing proportions of alumina to silica. The higher the quotient $\frac{Al_2O_3}{Si\,O_2}$, the greater is the amount of lime required to give more strength.

"The most favorable proportions are, approximately: lime to silica to alumina = 46 : 30 : 16. Good results are reached only when the slag is granulated when very fluid and in a strong current of cold water. To obtain a good cement, fine grinding is most important."

Particular attention must also be paid to the lime to be added proportionally to the ground slag. The lime should be slacked to a dry lime hydrate. In France the lime is slacked in baskets, which are filled with the burnt lime and dipped into barrels filled with water. The lime, saturated with water, is then thrown into heaps which are then covered with sand mixed with lime.

Later methods have, by the introduction of steam, considerably improved this crude manner of slacking the lime. The slacked lime should feel as fine as flour. For this reason it is recommended to grind twice; first alone, and then with the slag, as this will give a more perfect mixture. The slacked lime can be kept for a long time without losing its usefulness.

The results of the most exhaustive experiments have shown that cement made from furnace slag belongs to those hydraulic mortars which are particularly valuable for use under water, and in the soil or in a damp atmosphere.

In order to give an idea of the differences in furnace slag and in the analyses of different cements I beg to append here a table giving such information as I have been able to gather:

ANALYSES OF CEMENTS.

	James River, by V. M. I. Inst.	Fred Smith, Portland.	Fred Smith, Roman.	Engineering News.	Howard Fleming, Portland Imported.	Swedish Cement.
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
Silica	49.5	25	22	30.56	23.63	21.25
Alumina	11.2	8	7	13.31	10.87	6.47
Lime	25.1	60	55	45.01	59.47	64.00
Magnesia	14.0	. . .	. . .	2.96	. . .	1.41
Oxide of Iron . .	. . .	. . .	12	.25	. .	3.43
Impurities	. . .	7	. . .	7.00	6.03	3.41
Total	99.8	100	96	99.09	100.00	99.97

Analyses of Slags.

	Roanoke Iron Co.	Crozer Iron Co.	Pulaski Iron Co. No. 1.	Pulaski Iron Co. No. 2.	Pulaski Iron Co. No. 3.	Prof. Tetmajer (most favorable condition).
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
Silica	34.48	38	38	38	35	30
Alumina	26.30	9	11	13	17	16
Lime	30 29	35	34	32	43	46
Magnesia	6.27	16	13	15	1	. . .
Oxide of Iron, etc. .	2.37	2	3	. . .	2	. . .
Total	99.71	100	99	98	98	92

From the above table it will be seen that there is as much difference between the analyses of the different cements as there is between those of furnace slags. Referring to Professor Tetmajer's paper, however, we see that the slag should be basic, which means that the percentage of silica should be below 39 per cent., which is particularly the case with the No. 3 slag of the Pulaski Iron Company, and, as I understand this matter, there is no reason why a slag of this kind should not make a good cement if mixed with the proper proportion of lime.

In conclusion I beg to refer to the accompanying plate, showing a layout plan for a complete slag cement factory, as designed by Messrs. Pfeiffer Bros., of Kaiserslautern, Germany.

The slag is first conveyed through an arrangement of dippers *A* to the drying kilns *B*. After it is released from the kilns, at the foot of the ovens *C*, it is spread out for cooling; or, if it has been sufficiently cooled, it is passed on through another set of dippers *D*, to the "Jochum" mixer and separator *E*, and thence to the funnel *F*.

The lime, after having been burnt, is slacked, and is then moved up and down by means of the double elevator *G*. While undergoing this operation, it is contained in wire baskets, which are dipped in water by the elevator and again elevated. The lime is then dumped into the silos *I*, and here it must remain for a while, the longer the better. After the required rest the lime is taken from the bottom of the silos, and elevated through a shaft *K* to the second funnel of the Jochum mixer and separator. The Jochum apparatus answers the purpose of dividing the slag and lime in certain proportions and of mixing them thoroughly. The lattter operation is performed by a mixing screw *M*, on leaving which the material is then carried by another mixing screw to the four horizontal ball mills *N*, where it is ground into cement. It is then ready for use.

The cement is carried by screws *O* to the storage bins *P*, where it remains until it is barreled or bagged for shipment.

The total estimated cost of the machinery of such a plant is about $13,000. This estimate, however, could be considerably reduced by obtaining a majority of the machinery in the United States. The plant would produce 24,000 kilos per ten hours' work, or 36,000 barrels of 400 pounds each, per year, which of course could be doubled by employing a night shift.

That cement from furnace slag is coming into competition with the best Portland cement is a fact which can no longer be disputed. I quote from a pamphlet issued by Howard Fleming, 23 Liberty Street, New York, Importer of Portland Cement:

"Slag cement has been for some time manufactured in Germany, and works have been started in England for its production. Being a mechanical mixture of iron slag with slacked lime, it is very different in constitution from Portland Cement, which is a true chemical combination!!! Cement (Portland) adulterated with slag and slag cement, will be found finer ground and quicker setting than Portland Cement, and it will obtain its maximum strength at a shorter date than the best Portland Cement, etc., etc."

From the above it seems to me that all the differences mentioned as faults are rather in favor of the mixing of Portland cement with slag cement, or in favor of the use of pure slag cement.

The manufacture of cement from furnace slag is no longer an experiment but a fact, of which advantage should be taken in the United States. So far as I am informed, there is at present no manufacturing concern of this kind in the United States.

From reliable statistics I find that the imports of Portland cement into the United States in 1892 were 2,686,921 barrels. There is, as is well known, a large amount of Dusseldorf and Stettin cement brought into the United States yearly, so that a safe estimate of imported cements would probably bring up the total to 5,000,000 barrels per year.

In conclusion, I beg to quote from the *Progressive Age* of November, 1894:

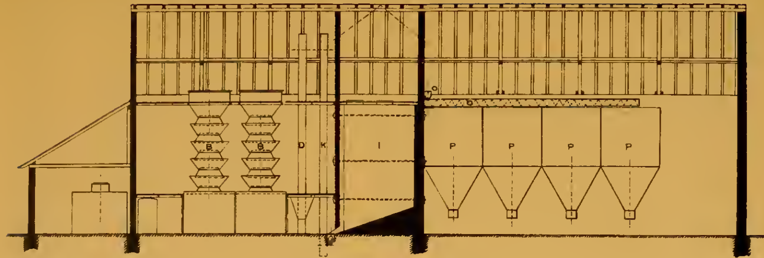
"*Portland Cements.*—We come now to a class of cements, says Ross F. Tucker, in the *Brick Builder*, which are so well known as to require little description. They are artificial cements, the product of scientific investigation, and the perfection of the principle underlying all cement hardening. By analysis and constant experiment the exact proportions of lime, silica and alumina necessary for the production of the most perfect union have been determined, and the mechanical processes for mixing, burning and grinding have been so perfected as to produce a

cement, the quality of which leaves nothing to be desired. They are, for all practical purposes, absolutely uniform in quality; they develop tremendous strength in concrete; they are economical, and may be used with large proportions of aggregates; they are invariable in color, and for hydraulic qualities have no rival. *The German Portlands are the finest in the world in all respects*, and an engineer may be at ease when his work is being done with these standard cements. The English Portlands are more variable, coarser ground and less economical. The process of manufacture differs widely in the two countries, and possibly the characteristics of the people of the two nations are shown in the results of their work.

"The Portland cements of American manufacture have a long road to travel before reaching the standard of excellence achieved by our rivals across the water; but with the great quantities of material suitable for this work at hand, it is only a question of time when American ingenuity will devote itself to the production of a domestic cement of equal quality with any in the world.

"The writer is not aware of the existence of a cement plant in the United States in which the production is carried on precisely as in Europe, nor is the term 'Portland' justly assumed by a great majority of American cements. It is doubtless true that several grades of domestic cement have attained a high standard and are suitable for use in important work, but they are few, and extraordinary care must be observed in their use, and every precaution taken to guard against the great bugbear—variation—for until that is absolutely overcome no cement can hope to take precedence of excellent products, which by long and successful use have proven themselves worthy of the highest regard, and which have won for themselves the first place in the confidence of professional builders."

No doubt the German Portland cements here referred to are artificial cements, made principally from furnace slag and other mixtures, for, so far as I know, there are in Germany no natural cement stones from which cements could be made.



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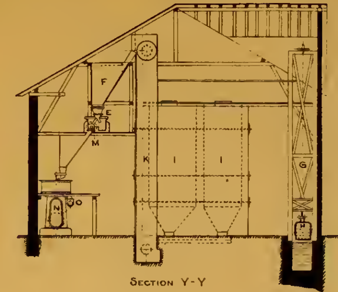

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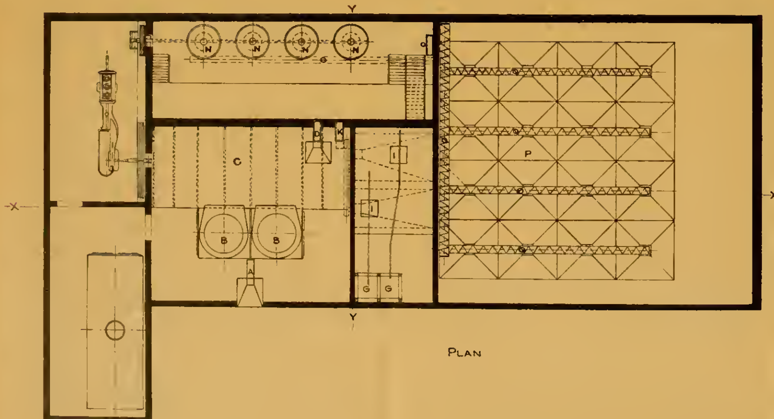

PLAN

GENERAL PLAN
OF A
GERMAN FURNACE SLAG CEMENT FACTORY
AS DESIGNED BY
PFEIFFER BRO'S OF KAISERSLAUTERN

SCALE OF FEET

0 5 10 m

THE CONTRIBUTION BOX.

Members of the associated societies, and other persons, are invited to send to the Secretary, for this department of the JOURNAL, such matters of general interest as may come to their notice.

The Technical Society of the Pacific Coast.

This society, the last of those recently admitted to the Association, is far from being the least. Organized in 1884, with a membership of 126 members, it numbered 219 members in 1892. Since then, owing to the business depression which has prevailed throughout the country, its numbers have been reduced until it now numbers about 170 members, of whom about 100 are resident in San Francisco.

This, however, appears to be one of those societies which should be estimated not by number but by weight. Representing, as it does, that remarkable section of our country where nature seems to have given occasion for the exercise of engineering effort upon the grandest scale and in a vast number of novel directions, its membership has always been made up largely of giants in the profession.

The first president of the society was Col. George H. Mendell, of the U. S. Engineer Corps, whose paper describing the use of concrete at Fort Point was printed in our JOURNAL for March. He was ably seconded in his official duties by the late George J. Specht, the first vice-president, who was one of the founders of the society, if not, indeed, its father.

The recent remarkable progress of the society is attributed to the activity and earnestness of Mr. John Richards, past president, a mechanical engineer of wide reputation and unusual skill, two papers from whose pen will appear in an early number of the JOURNAL. Mr. Richards' paper on Abrasive Processes in the Mechanic Arts, published in the Transactions of the Society for 1891, is regarded as one of the most interesting and valuable of the society's papers, and one which may justly be called classic. Mr. Richards is at the same time editor of *Industries*, a well-known magazine devoted to science, engineering and the mechanic arts.

The regular meetings of the society are held on the first Friday evening of each month.

The society's papers will now reach an audience many times greater than ever before, and it is confidently hoped that its influence will be even more widely recognized and appreciated.

The Engineers' Society of Western Pennsylvania.

This very important society is now considering the advisability of becoming a member of the Association of Engineering Societies.

In the JOURNAL for January, our Librarian, reviewing the January number of the proceedings of this society in which the cost of "printing and binding" for 1894 was given as $1388.50, assumed that these figures covered simply the cost of issuing the proceedings, and instituted a comparison showing that their cost on this basis was $3.94 per page as against $3.26 for the JOURNAL of our Association.

Since then, however, he has learned from the secretary of the Western Pennsylvania Society that the sum named included a re-issuing of the proceedings to each member at the end of the year, the preparation of circulars and meeting notices, etc., etc., leaving only $594.15 as the cost of publication of the ten monthly numbers issued during the year.

On this basis, the task of demonstrating the economy of co-operation, although still an easy matter, is, of course, materially less simple than before.

As stated in our January JOURNAL, the total number of pages of the society's proceedings, including advertisements, blanks, covers, etc., was 352, making the cost per page $1.69, while the 1290 pages of our JOURNAL cost, for the corresponding items, $3.26 per page, or nearly 100 per cent more.

The pages of the society's proceedings, however, excepting those devoted to advertisments and covers, are in small pica and average about 365 words each, whereas our papers are set in long primer and average about 513 words per page, while the nonpareil pages of our index last year contained 100 more. The 94 pages (not including advertisements) of our October JOURNAL, which is a fair example, averaged 524 words each.

Reducing the two publications to the same number of words per page, we have $2.43 as the cost of a page of the Society proceedings, as against our $3.26.

It must be borne in mind again, however, that our aggregate membership last year was nearly 1200, as against, say 450 for the Western Pennsylvania Society. Taking this into consideration, we find that with pages of equal size the cost per 100 member-pages to the Western Pennsylvania Society and to our Association were 54 cents and 27 cents respectively.

Or, reciprocally, assuming, for convenience, that all the pages of the two publications average respectively 524 and 365 words per page, we find that the 1290 pages of our JOURNAL, supplied to nearly 1200 members at a cost (covering corresponding items) of $4,205, furnish over 192,000 member-words per dollar, while the 352 pages of the Society proceedings, supplied to, say 450 members, furnish less than 98,000 member-words per dollar.

It appears that the cost per member per annum to the Society in question is now, say $1 32, whereas the cost to the members of the societies in the Association for the same items during last year was about $3.50, or nearly three times as great; and in the case of a society which was barely holding its own financially this would of course be an important consideration, however desirable it might be to be furnished with over five times the amount of matter, at less than three times the cost; but to a society so eminently prosperous as the one we are considering, it would seem that this consideration should have but little weight.

It is needless to point out that the foregoing comparison takes into consideration merely the *mass* of material furnished, with no regard to its character or variety, and that however valuable the proceedings of any one society may be, it is of great importance to its members that they should have furnished them, in addition to their own papers, the results of the work of eleven other societies, including those of Boston, Chicago, Cleveland, St. Louis and San Francisco, especially when the union between these societies extends, as ours does now, from the Atlantic to the Pacific and from Virginia on the south to Montana on the north.

Canals Joining Lake Erie and the Ohio River.

Cincinnati and Pittsburg are active in the promotion of schemes for ship canals to connect their respective cities with Lake Erie, and thus with the St. Lawrence River and the ocean.

In February, 1894, Mr. M. D. Burke read, before the Engineers' Club of Cincinnati, a paper outlining the project for a ship canal from Cincinnati to Toledo, and setting forth its importance. The old Miami and Erie canal now connects the two cities, crossing a summit 393 feet above Lake Erie and 513 feet above low water in the Ohio at Cincinnati. It is believed that by introducing a system of slack-water navigation in the Miami and Maumee Rivers, emptying respectively into the Ohio and into the Lake, and by similarly improving the Licking River, which flows northward through Kentucky into the Ohio opposite Cincinnati, an outlet will be afforded for the soft coals of the eastern Kentucky fields.

Mr. Burke makes an earnest protest against the commonly accepted statement that canals, as transportation lines, have been superseded by the railroads. While this may be true in itself, Mr. Burke urges that the disadvantages under which the canals have labored should be taken into consideration.

The Pittsburgers are considering the construction of a canal from their city up the Ohio and Beaver Rivers to the junction of the Shenango and Mahoning, just below Newcastle. From this point two principal alternative routes are being considered, one via the Shenango reaching the lake at Conneaut, the other via the Mahoning to Geneva, near Ashtabula.

The provisional committee on engineering, consisting of five members, of whom Mr. Thomas P. Roberts, Chairman, and Messrs. W. L. Scaife and E. M. Bigelow are members of the Engineers' Society of Western Pennsylvania, have made a preliminary investigation of the country embracing these routes and have made a generally favorable report upon the project. The length of either route would be approximately 130 miles. The summit is 316 feet above the Ohio at Pittsburg and 443 feet above Lake Erie.

While it would of course be premature to make a close estimate of the cost without actual surveys, the committee submits a preliminary estimate making the total cost $26,500,000, in round numbers.

Electrical Heating.

At a meeting of the Engineers' Club of Philadelphia on April 20th, Mr. J. Chester Wilson presented a paper upon this subject.

He referred to the use of the arc lamp by Cowles fifty years ago for obtaining heat in reducing aluminum. Electric flat-irons and glue-pots were shown, employing the incandescent principle, and various forms of street-car heaters using the same principle were described and illustrated.

In the discussion it was stated that the Niagara Construction Company offers to supply power in Buffalo at the rate of $22.00 per horse-power per year, the power to be maintained constantly through the twenty-four hours.

Mr. Carl Hering referred to the electric heating of the Vaudeville Theatre in London, which, he understood, involved no increase in the expense.

In reply to the suggestion that while electric heating might do for trolley cars in temperate climates like that of Philadelphia, it would be found wanting in more northern cities, Mr. James Christie stated that in Canada he had found cars heated fairly comfortably while the thermometer was at 30° below zero.

Does Cast-Iron Expand or Contract at the Moment of Solidification?

The Collector had the good fortune to attend a meeting of the Engineers' Society of Western Pennsylvania on April 18th, when Mr. E. D. Estrada described a series of experiments he had made with the purpose of answering this question. Mr. Estrada referred to the experiments of Robert Mallett, described before the Royal Society in 1874, from which, finding that the specific gravity of the molten iron was less than that after solidification, he inferred that contraction took place in solidifying. In 1879 and 1880, Mr. Wrightson appeared to have demonstrated, before the Iron and Steel Institute of Great Britain, that the reverse of this was true, and that the iron increased in volume in the process of solidification.

Mr. Estrada placed a wrought-iron tube in the center of a flask and then surrounded the tube with molten iron. When the tube became red hot it was filled flush with liquid iron from a hand ladle. Immediately after the tube had been filled, the upper surface of the iron in it was chilled by means of waste previously soaked in cold water. Soon after this, molten iron began to ooze from the top of the tube, solidifying quite readily. From this and from other and nearly similar experiments with like results, Mr. Estrada arrived at an affirmative answer to the question proposed.

It was suggested, however, during the discussion, that the oozing out of the molten metal from the top of the tube might have been due, not to its own expansion, but to the contraction upon it of the tube containing it.

THE LIBRARY.

It is proposed to notice briefly, in this department of the JOURNAL, such engineering publications as may find their way to our shelves.

Publishers are requested, in sending works for review, to state the prices of same.

The Washington Bridge.—The Library has received, with the compliments of the author and of Mr. Leo Von Rosenberg, publisher, New York, a copy of Mr. William R. Hutton's monumental work bearing the above title. It is so well and so favorably known to the profession that anything like a review of it at this day would scarcely be in order, but no apologies will be needed for expressing here our thanks for the compliment.

Meteorology. By Thomas Russell, U. S. Assistant Engineer. Macmillan & Co., New York and London, 1895. 8vo. $4.00.

This book will be found convenient as a work of reference. The phenomena of weather are here defined, and what is known respecting them is ably and concisely stated. The degree of reliability of forecasting from various classes of phenomena is discussed. Thirty-five pages are devoted to instruments, their sources of error and corrections and proper exposure, and about fifty pages to weather maps and forecasting. Rivers, floods and river-stage predictions are fully treated. Twenty typical weather maps are reproduced, and sixty more show average depth and frequency of rain during days before and after the occurrence of such weather as is represented by each of the twenty typical maps. The maps are printed in three colors. The book, in its make-up, is a model of what such a work should be.

Asphaltum. NATURAL —, AND ITS COMPOUND. A paper prepared for the use of the professors and students of the Rensselaer Polytechnic Institute at the request of the Rensselaer Society of Engineers. By J. W. Howard, B.L., C.E., Troy, N. Y. 27 pages.

The author has set for himself the task of presenting in convenient form the facts which every one, or at least every engineer, must want to know about asphaltum and its various combinations, and he has used excellent judgment in his selections. The various forms under which asphaltum, or asphalt, appears, are defined, and their properties and principal localities are stated. The paper closes with a history of the development of the asphalt industry and a brief synopsis of its statistics.

Society Proceedings.

AMERICAN SOCIETY OF CIVIL ENGINEERS. *Transactions of the* ——. Vol. XXXIII, No. 2, February, 1895.

This number is devoted to the presentation of a notable paper by Mr. William Hamilton Hall, describing the Santa Ana Canal of the Bear Valley Irrigation Co. in San Bernardino Co., Cal.

The main object of the canal is to take water from the Santa Ana River, reinforced, when necessary, during irrigation months, by waters drawn from the storage

reservoir within the river's water shed in the San Bernardino Mountains, and supply it for irrigation and domestic uses throughout some 45,000 acres of the northern portion of the San Jacinto Plateau or Valley. The work, like others in that remarkable country, calls for a number of operations of the most striking and picturesque character, including three pressure pipes of redwood staves bound with round steel rods, and working under heads of 150 feet or more. The work is very thoroughly illustrated, not only by scale drawings but by very striking photographic views.

Franklin Institute. *Journal of the* ——. Philadelphia, April, 1895.

This number contains a paper, by Mr. Vaughan Merrick, describing and illustrating the City Avenue highway bridge over the Schuylkill River at Philadelphia. Mr. L. Y. Schermerhorn, President of the American Dredging Co., contributes a lecture on the Rise and Progress of River and Harbor Improvement in the United States.

The Institute, which has, almost from its beginning, occupied a small and utterly inadequate building in the older business portion of the city, is now making a determined and promising effort to place itself in quarters where it will have some opportunity of demonstrating its eminent usefulness, and the number before us contains a valuable historical and statistical sketch of the Institute and of its activities, prepared by the Secretary, Dr. William H. Wahl.

Engineers' Society of Western Pennsylvania. *Proceedings of the* ——. Vol. XI, No. 3. March, 1895.

The feature of this number is a valuable paper by Mr. Harry J. Lewis, on "Soft Steel for Bridges," accompanied by tables showing what is required of steel in various bridge specifications at the present time as compared with those of two years ago.

The tables show a marked progress in the recognition of the advantages of soft steel, and a decided movement in favor of the use of the open-hearth process. The paper was discussed at considerable length by Messrs. Emil Swensson, Max J. Becker, A. D. Wilkins and others, including the President, Mr. Thomas H. Johnson.

Alabama Industrial and Scientific Society. *Proceedings of the* ——. Vol. II, No. 4, 1894.

By an awkward typographical error, the proceedings here given are set down as being those of December 14, 1895. The number contains papers on Spathite Iron, by M. C. Wilson; Dust-Catcher Refuse, by William B. Phillips; and The Formation of Cyanides in the Blast Furnace, by C. A. Meissner.

Spathite iron is said to be made only at Florence, Ala., and from an ore which comes only from Iron City, Tenn. The name seems to have been unfortunately chosen, inasmuch as the ore is not a true spathite, but a mixture of red hematite with carbonate of lime.

ASSOCIATION OF ENGINEERING SOCIETIES.

Organized 1881.

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THE INDUSTRIAL PROBLEM OF THE PACIFIC COAST.

I. Address of the Retiring President,

MR. C. E. GRUNSKY.

[Read January 19, 1895.*]

IN giving way to your newly elected President, I desire to express my appreciation of the interest manifested at all times by the membership in the work of the Society, and to thank the individual members of the several Boards of Directors for faithful help and earnest endeavor to keep this a progressive organization, with a steadily increasing field of usefulness.

Our meetings have been well attended and there has been abundant material offered for discussion, through which we have been kept in touch with the progress being made on this coast in the practical application of science.

It is not my purpose at this time to attempt a review either of the several papers read before us, nor of the scientific, architectural or engineering work on this coast, but in view of the general depression of business, particularly in certain pursuits in which this State is interested, notably general farming, horticulture, viticulture and manufacturing, it may not be out of place to venture a conjecture as to the field in which further development will be most rapid on this coast.

* Manuscript received April 25, 1895.—*Secretary, Ass'n Eng. Socs.*

It must be apparent to every one that the low prices of manufactured articles as well as of products of the soil indicate general overproduction.

It will take years before any great betterment of prices by reason of an adjustment of production to demand can be brought about, and this adjustment must mean either the abandonment of many of the less favored industries or a reduction of wages, unless means be found to increase consumption of products.

It is not therefore probable that our most rapid development of resources is to be sought in the direction of increasing products of speculative farming or of general manufactures, even though the lack of profit in speculative farming may compel the introduction of more diversified field crops.

The industry which bids fair to be stimulated directly by general business depression instead of suffering thereby, is mining, and particularly gold mining. The fall in price of raw materials, manufactures and wages means nothing else than a rise in the value of the metals used as mediums of exchange.

Preferred investments for capital will therefore be made in the direction of reopening such old mines as can now be profitably worked, new mines will be sought for and developed, and the field for such operations on this coast, and particularly in California, is exceptionally good.

But in suggesting possibilities of improvement in the mining industry, I do not wish to be understood as encouraging that portion of the business which is confined to the stock exchange, but mining as a legitimate business, which, in view of the almost virgin condition of the greater portion of the mineral fields on this coast, may be said to be still in its infancy.

Hand in hand with the development of the mining industry and as a factor in making such development possible, will come the utilization of power to be generated by the flow of our mountain streams. By electric transmission it can be delivered at those points where it will be of greatest service in reducing cost of manufactures, it will enable and encourage the establishment of industries which, without it, would have been impossible.

In these two directions, mining and power development, combined with electrical transmission, and in the general tendency which seems manifest throughout this coast for municipalities to have their own water and light works, the engineer sees a ray of hope for increased demand for professional services.

And now a word about the general business depression. Overproduction is only another name for a lack of consumers of our products,

and it is clearly evident that a reduction in the cost of production is not the most desirable remedy with which to correct the prevailing low prices. This reduction would mean either a reduction of wages of labor directly employed in production, or reduction of the expense of marketing the product, consequent upon which there must follow reduction of wages of the employees of transportation companies and of merchants.

Permanent relief then should be sought in another direction, in the direction of increasing the number of consumers, though not necessarily by seeking new markets. It is well known that the method of increasing consumption by bringing this country into direct competition with countries where low wages are the rule, can have but one result—the gradual but inevitable reduction of wages to the lowest standard, determined on the basis of nearness to foreign markets, coupled with the infliction of injury upon the industries of other countries, or, possibly, other sections of our own country. The increase of consumers should rather be secured by increasing the proportion of population engaged in non-producing pursuits.

Assume for a moment that our present system of indirect taxation be completely abolished, except in so far as made necessary for the protection of manufacturing industries, and all revenue for the support of Government be secured by a system of direct and equitable taxation, and that under intelligent and judicious direction large sums of money be expended in the execution of public works, and for purposes of scientific research, and in the interest of education, the result would be that all the money thus expended would be put into the hands of non-producers; it would come into circulation through the best possible channels; it would be paid out principally for labor, and through the laborer it would find its way to the butcher, the baker, the manufacturer of clothing, of shoes, of hats, and through these again to other dealers and agents and laborers innumerable, yet all consumers of each others' products and all jointly interested in maintaining a large and rapid circulation of money, a great volume of exchange of products.

The time will come when we must depend almost exclusively upon a home market for our products, and all legislation, all agreements with foreign powers, should be shaped with this fact in view. To have something to sell to our neighbors is certainly desirable, but to have to abandon the fertile wheat fields of our great central valley, the fruit farms of our coast counties and foothill regions, the vineyards of Sonoma and Fresno, the orange groves of central and southern portions of the State, merely because the market beyond the limit of the United States is closed to our product, would certainly be a calamity, and it is well to be prepared to avert this calamity.

There are now annually expended by the United States for river

and harbor improvements about $20,000,000. This money is expended for salaries, general expenses and, through contractors, for labor. All of those depending upon the expenditure of this money for a livelihood, again expend practically all of it for necessaries and comforts of life. In the form of profit it becomes a factor in building up the wealth of individuals.

But if money be taken by equitable taxation from those who have by accident or natural qualification been placed in a position to accumulate beyond their immediate personal needs and desires, then the more that be taken and put into circulation through such channels as the construction of public works, the greater must be the general prosperity of the nation. This remains true entirely independent of the aggregate amount of money in actual circulation.

Suppose for a moment that the business of the country, national, state, municipal and individual were conducted on the basis of a rapid instead of a slow circulation of the medium of exchange, it would give the money-getter increased opportunities, fully equal to the increased taxation necessary to accomplish this; it would increase the opportunity for earning a livelihood by physical and mental effort; it would stimulate varied production by the agriculturalist with a tendency to less speculative farming; it would have the best possible effect on the advancement of civilization, the betterment of the human race; it would engender permanency of our industrial conditions.

It has always been the policy of our government, national and local, when times are hard, and business is depressed, to reduce taxation, to curtail expense, to cut down salaries, to enforce the gradual degradation instead of the elevation of the nation. This policy is wrong, yet it must be admitted that there has been some excuse for it. Under our system of indirect or unequal taxation, supplemented by fraudulent assessment, the sudden reversal of this policy would for a time at least bear too heavily upon the very best element of our commonwealth, upon the citizen whose entire savings are represented by the home which shelters his family and which is always taxed proportionately far in excess of large holdings and of property not as tangible as real estate.

But let direct taxation for national purposes be once introduced, as it could be without material expense in the matter of collection of taxes, and it will not be long before means will be found to secure from the wealthy their full quota.

Self-interest should prompt every citizen of the United States to favor such a policy as here briefly indicated.

The opportunities for judicious great increase of expenditures in so far as the general government is concerned, will readily suggest themselves.

Public works, such as river and harbor improvements, coast defenses, the construction of war vessels, the maintenance of an efficient navy and army, the maintenance of bureaus for research: agricultural, geological, astronomical, orographic, hydrographic, hydrometric, meteorological; the construction of public roads, canals, railroads, the liberal support of institutions of learning, and for the study and encouragement of the fine arts, are but a few of the many.

Such a policy would by no means impoverish the nation, no matter what limit be set for the annual expenditure, provided that due consideration be always given to the necessity of keeping the money expended, at home; a circulation of money must be established similiar to the circulation of the blood in the human body. Government may be likened to the human heart. By an equitable system of taxation it should cause a steady flow of money toward its coffers, and by honest expenditure for purposes as above indicated, a healthy return flow should be maintained, which would be felt to the limits of the land.

To some extent this policy prevails abroad. Look at France, at England, at Russia, at Germany, and consider for a moment the enormous expense entailed by the maintenance of armies and navies. The question may well be asked: is such maintenance a burden? and there can be but one answer. The expense of maintaining armies will never bankrupt any nation of varied resources so long as it be maintained by home products. This expense may be likened to the fly-wheel of the steam engine, it keeps the affairs of the people in smooth grooves. The host of people supported at national expense as non-producers, affords the market for the products of the reduced number of producers. The taxation for the maintenance of the army is not oppressive, so long as that very army enables the producer to make a profit, which would otherwise be out of his reach. But in our own case it is not necessary to maintain a numerous army in order to increase the proportion of non-producing population, it can be done in much more useful directions as already suggested.

It appears, therefore, that all money expended by the nation for useful, ennobling work, should not be considered a national expense at all. The money thus expended not only serves as an agent to create public buildings, works of art or a good war vessel, as the case may be, but by supporting non-producers it is of direct benefit to every producer and wage earner in the country, and every time it is withdrawn from those who are hoarding it and is sent forth again for distribution to those who have been less fortunate in making their labor profitable, it repeats its good work.

Without any attempt to elaborate this idea it does appear that the prosperity of the country should not be measured by the money in circu-

lation, but that it is rather the product of the amount by the rate at which it is made to circulate, and that every well-regulated country has it in its power to control the rate of circulation, by equitable taxation and liberal, well-distributed expenditures.

THE INDUSTRIAL PROBLEM OF THE PACIFIC COAST.

II. Inaugural Address of the President,

MR. GEORGE W. DICKIE.

[Read January 19, 1895.*]

Members and associates of the Technical Society of the Pacific Coast:

I consider it an honor to be selected by you to preside over the destinies of this Society for the coming year, although you may not be doing yourselves an honor by such a selection.

I am afraid that my only qualification for this office is an earnest desire to see this Society realize the hopes of its warmest friends. If this desire of mine could only be combined with the wisdom required to bring about the realization of these hopes, we would begin to-night to make progress towards a wider field of usefulness than we have hitherto occupied. It is, therefore, to be hoped that your board of directors will be able to supply my lack of wisdom, and thus realize your brightest hopes.

Finding myself in the position that demands that I should address you to-night on some subject that would in some way touch on the many and important interests represented by the members of this Society, I began to bethink me how I could best meet that demand. It is the usual custom for such addresses to take the form of a review, showing the progress made during the year past, in the sciences or industries representing the work in which the Society's members are engaged; but, in looking over the past year for some inspiration from the application of science to the advancement of the industries of the Pacific Coast, I have found little to encourage me to make that alone the theme of my discourse.

It will profit us nothing to go on discussing the technical details of engineering or chemical science in its application to any of the industries now existing or likely to be established in our State, if such industries are not surrounded by conditions favorable to their existence. What would we think of a doctor who, when called upon to resuscitate a drowned person, should begin to doctor up the external injuries, rubbing

* Manuscript received April 25, 1895.—*Secretary, Ass'n Eng. Socs.*

liniment on a bruise here, and binding up a wound there, instead of devoting his whole attention to getting the breathing and circulating organs to perform their proper functions?

The immediate duty of this Society, and of all similar organizations that come into touch with the material interests of this State, is to help, by every means in their power, in the creation of a sound, vigorous and patriotic sentiment in regard to the development and expansion of every interest that naturally should live and thrive amongst us.

The time and conditions are upon us when we must, for a time at least, give up the discussion of small questions of technical detail, and join in a grand and general movement for the revival and extension of the industrial and commercial interests of the Pacific Coast. Joining in such a movement may not be quite in keeping with the proper functions of this Society, but when the existence of our industries, and with them the extension of our commerce, is in danger, the discussion of technical matters of detail relative to any branch of either of them is simply an evidence that those interested are too busy with their own individual concerns to pay any attention to the general problems that at present confront us.

The exact method or manner in which we are to work is not the main question with those of us who have been struggling to establish industries in this State, but whether we are to have the chance to work at all, is the question of to-day with which we stand face to face. This is not an industrial or a technical question; it is a community question, and an affirmative answer must be the result of laying aside individual selfishness and fostering of enterprises, the prosecution of which tend to the development of our material interests as a community.

I am fully alive to the difficulty of bringing about anything like a unity of sentiment in a community like ours, built up of material from all parts of the earth, whose habits of thought and methods of work are as widely apart as the places from whence they came. And yet, this very thing must be brought about before our commercial or industrial enterprises can become prosperous or enduring.

As an illustration of how the particular method of doing a thing will often become the subject of discussion, instead of the vital question as to whether the thing should be done at all or not, I will give the following from a paper of mine read before the last meeting of the Society of Naval Architects and Marine Engineers in New York:

"There is a grand opportunity for the establishment of a great American steamship line in the trade between San Francisco and New New York via the Straits, taking in the principal seaports of the South American Continent. We believe that a business could be built up to admit of two steamers per month, having a general freight capacity of

6,000 tons each. These vessels should have speed enough to insure 65-day trips, and should have first-class accommodations for a limited number of cabin passengers between way ports. They should have cold storage compartments, and such a subdivision of cargo space as would permit of a varied assortment of general products being carried. They should be designed so that in case of need the Government could use them for cruiser transports. They might also be partly or altogether manned by a naval reserve force, and thus form an excellent base of supply for the Navy. Such a line would open up great possibilities, both to our merchants and producers, and eventually would give us South America for a customer. In order to make such a line a success the ships must be first-class in every detail and especially designed for the work. They must have regular sailing days, not too far apart, and, in order to provide for these essentials, Government aid would be necessary for a number of years. This might be in the form of a mail subsidy, or a mileage rate, but should be liberal enough to insure a high-class service. The money thus spent would be as nothing compared to the benefits that would result to the trade of the country, especially that of California."

Quite a number of Eastern technical papers have been, since the reading of this paper, discussing that part of it just quoted, but not with the view of stirring up a sentiment favorable to this and kindred enterprises, having for their object the extension of our commerce; but first one and then another has devoted its space, and drawn the attention of its readers from the main question, by discussing the technical details of the plans by which I propose to carry out such an enterprise. One said, "Your ship must have twin screws and no masts." Another said, "You must have tramp steamers of the cheapest type, there being no need of carrying passengers," and another said, "There was no need for cultivating South American trade, and therefore no need to stop at way ports," while still another claimed that it would be wrong for the Government to help an enterprise when California was to receive the benefit.

Now, my object was not to advocate this, that or the other kind of tool for doing the work, but to point out the necessity for the work being done, and to bring about in the minds of those best able to carry out such an undertaking, the determination to join forces and do it.

Our mercantile houses and manufacturing establishments are suffering from atrophy, which, if not arrested, will result in a gradual extinction of all enterprise. This process is now going on, and the sad part of it is that as first one and then another enterprise has to be abandoned, others seem to think that the closing out of their neighbor and competitor will in some mysterious way be an advantage to their business.

This selfish indifference to the general condition of the trade or indus-

try in which the individual may be engaged or interested as long as his own particular business survives, is the principal obstacle standing in the way of a general revival of industry and commerce in our State.

The general apathy so prevalent, and which is so fatal to all our material interests, must be dispelled before any revival of trade can be expected.

There should be an understanding amongst ourselves as to what industries naturally belong to this State, and these should be fostered and protected. Wise legislation is required in order to encourage the establishment amongst us of such industries as the natural products of the State would warrant us in believing would cause to become strong and prosperous.

Public burdens should, as far as possible, be removed from industrial enterprises, the prosecution of which requires the employment of great numbers of skilled and unskilled people.

It is such establishments that create values that in time become the foundations of all public revenue, and to weaken or destroy the source from which these values spring, is to kill the goose that lays the golden egg.

The great question of transportation has, during the past two or three years, kept our merchants and producers in a continual state of excitement without any permanent satisfactory result. The reason of this unsatisfactory result is the same want of unity of aim and action on the part of those interested, greatly aggravated by a stupid fight against what are called the exactions of the Southern Pacific Company. This company, with all its allied interests, in my opinion, is the only thing of life in our State to-day, and if it owes its vitality and power to the subjugation of all other interests, it has simply succeeded in doing what every business man tries to do, and its success, like all other successes of the same character, is not so much owing to the superior skill and enterprise of its managers, although that is no doubt of a high character, but largely to the want of enterprise and united action on the part of those who are loudest in their complaints against the power that holds them in subjection. Naturally, California is well fitted to be a great commercial and manufacturing state, with a climate well adapted to the prosecution of every kind of manufacture. With a soil that richly repays the labor bestowed upon it, and set right in the centre of its great coast line, one of the finest harbors of the world, why should we not take a better position than we do now in the manufacturing industries of this country, and in the commerce of the world? Our merchants, most of whom came here from the Eastern States to open branches of houses established there, have kept on doing business with their faces turned toward the East; have built their business houses with their fronts facing

in the same direction, and standing in their front doors, wondering what has become of their business. They can see nothing but the railroad, with the towns along its route getting their supplies from the west-bound trains, because they happen to be at the far end of it.

Now, if these merchants would just turn their business houses around so as to face the other way, they would be at the beginning of the railroad instead of being at the end of it, and loaded trains would leave their back doors, instead of empty cars standing at their front doors, and the railroad would do just as well hauling east as hauling west.

It is not necessary here to point out the means by which this change is to be accomplished. I have already done this, as far as the matters on which I have any knowledge are concerned; but my proposals have hitherto been in advance of any desire on the part of our merchants to profit by them.

To-night I desire to enlist all the members of this Society and all those whom they can influence in a united effort, to help revive the manufacturing industries of this State, and the commerce of San Francisco. Every influence has an effect, and we can all do something in this direction. Consulting Engineers should advise their clients in regard to favoring the products of our establishments. Nothing but an inability to produce the article required should be an excuse for its being made elsewhere. We can never be prosperous until we supply a larger percentage of our requirements from the results of our own labor. A large portion of the youth of our State are now growing up in a condition of enforced idleness, which adds to the already heavy burden of the few who have the opportunity to work. We are opening schools for manual training in the mechanical arts, and at the same time closing our workshops. What good will come of teaching trades in our schools and not fostering the practical application of such knowledge in our industries? There is a young generation, to say nothing of their fathers, begging at our shop doors to-day for the opportunity to earn a living at their trade; but the industrial wheels are either stopped or moving so slowly that there is no chance for them to work, and this in a young State with vast resources undeveloped, and which, from her position, should control the trade of the Pacific.

The Technical Society may not be able to accomplish very much in the direction herein indicated directly, but such societies have an immense power indirectly. Our members are being constantly brought into contact with business men representing large interests, and their advice and opinion very often goes much further than the party giving it is aware of. Let our influence be exerted continuously in the one direction of helping by every means in our power the growth and development of our home industries. Well-directed efforts patiently

kept up by technical men will ultimately result in the formation of a sentiment that will pervade the whole community, making legislation in the right direction possible, and when once our people understand the possibilities latent in the resources of this great State, there will be an awakening of dormant industries. Our merchants will find new markets for the products of our skill, and instead of driving labor from the closed doors of our factories, we will be inviting the idle hands of other States to help us meet the wants of customers in every land that looks on the Pacific.

THE RELATION OF RAILROAD TRANSPORTATION TO PRODUCTION IN CALIFORNIA.

By R. L. Dunn, Civil Engineer.*

[Read September 7, 1894.†]

In the Sacramento *Record-Union* of March 11, 1892, appeared a paper entitled "California Landholdings," written by Mr. W. H. Mills, who is a prominent official of the Southern Pacific Company. Though in it there is no reference to railroads or to railroad transportation in California, singularly enough, and probably unintentionally, it is specially of value as it throws light on railroads and railroad transportation in California. Surprisingly, because written by a Southern Pacific official, it is the most complete and correct statement of the results of the Southern Pacific Company's business policy that has yet appeared in print, and more conclusive and impressive in this year of 1894 than when written in 1892.

It is only fair to state that the writer seems to have been utterly unconscious of a possible significance of his elaborately gathered facts and statistics other than that presented by him. That they have a definite relation to the Southern Pacific Company's rates of fare and freight, is recognized by Colonel R. S. Morgan in his report to the Railroad Commissioners, Messrs. Beckman, Rea and Litchfield, in 1892, in which report he embodies a portion of Mr. Mills' paper as an exhibit,

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* Before reading his paper Mr. Dunn said:

Some two years since, in connection with my profession as a civil engineer, I was engaged in investigating the irrigation problem in Placer County, Cal., and I wanted to demonstrate, to men who had lands that could be cultivated, the desirability of irrigation. I examined the assessment rolls of the county to ascertain the difference between the value of lands that were irrigated and of those that were not. In making this examination I came across a number of other things of interest on the records, from which I made several tables. Just about that time William H. Mills, of the Southern Pacific Company, read a paper before the Chit Chat Club of this city, entitled "Large California Landholdings." This was printed in the *Sacramento Record-Union*, and afterwards in pamphlet form, and circulated all through this State. It happened that it was precisely the point that I had been investigating, and as the result of reading that, and as the result of my investigations, I prepared this paper. I have remodeled it somewhat, so as to bring it a little closer to the times and the date, and have entitled it, not "Landholdings in California," but "The Relation of Railroad Transportation to Production in California."

† Copy received April 25, 1895.—*Secretary, Ass'n of Eng. Socs.*

and in his argument uses the facts it states as a reason why the rates of fare and freight should not be reduced, but must be maintained.

Mr. Mills in his paper, by compilations of statistical figures taken from the census of population, shows a decrease in population of certain of the agricultural sections of the State, and by another set of statistical figures taken from the county assessment rolls, establishes as the cause of this decrease of population, the increase of large landholdings through the consolidation of small landholdings. Had the statistical figures of the freight and passenger traffic of the Southern Pacific Company for the same time and territory been given, the paper would have had the value of completeness as well as correctness. Apparently, however, Mr. Mills if he had these last statistics in mind at all in preparing his paper, considered them only as expressing one of the unfortunate effects of the decrease of population and of the increase of the monopoly of the land, and therefore not relevant, either to the consideration of the cause of that decrease of population and increase of land monopoly, or to the remedies desirably to be applied.

Mr. Mills states as a conclusion from his statistical figures and general argument, that the land monopoly developing in California is in the highest degree prejudicial to the best interests of society and the State, in that it is not only decreasing population and wealth, but is sapping at the very foundations of our political institutions. Realizing the necessity of society and the State destroying land monopoly before land monopoly destroys society and the State, he proposes certain legislation as the justifiable and desirable corrective to be applied. Considering the cause of land monopoly in California to be the rapid accumulation of wealth, that seeks investment in land largely for the security alone, and the facility with which land can be made the pledge for borrowed money, his proposed legislation would make: first, the use of land as security for debt practically impossible; second, the future accumulation of wealth in land illegal; and third, would force the distribution of land already so accumulated by prohibiting its succession by will. Questioning all of this proposed legislation, I realize that a discussion of it is profitless except as the statement of fact on which it is based is correct.

Is the cause of land monopoly in California what Mr. Mills states it is, or is there some other cause? Or, stating the question in another form, are Col. Morgan and the Railroad Commissioners right in saying that the decreasing population and increasing land monopoly justify the rates of freight and fare imposed by the Southern Pacific Company, or are they wrong? Are decreasing population and increasing land monopoly the causes of the condition of fares and freights, or is not the fact that the condition of fares and freights is the cause of decreasing population and increasing land monopoly?

Mr. Mills emphasizes the undesirable social condition forced on the small landholder as being the cause that eventually displaces him to increase the monopoly of the land. This small landholder, he very truly says, is deprived of opportunities of education and society for himself and his children, and must live a socially unpleasant, isolated life. This social condition, however, is itself an effect of the real underlying cause, which is the undesirable business condition of his small landholding. It does not pay. And it is because small landholding has become more and more unprofitable that it has become undesirable and has been given up, schools and churches disappearing with it. Anywhere in the State where small landholders are engaged in general farming and the production of the staples the same story will be told. Farming does not pay, and the small landholder is anxious to sell. For this condition of not paying there are several causes, some generally known and recognized, and others not. There is no question but that the great plains of the Sacramento and San Joaquin Valley no longer yield as much wheat to the acre as fifteen years since, and their production of wool, hide and meat is less in even greater ratio. There is no longer a relatively large local market of people who are not producers of agricultural commodities, the mining communities of this State and Nevada, and the local market that remains is partially supplied with the surplus of outside points of production. All staple agricultural products are lower in sale value in the outside markets of the world through the competition of cheaper areas of production. General business conditions have so changed that, quality being the same, the large producer has invariably the advantage of the market over the small producer. Where the small producer has to accept in transportation the general tariff of the railroad, the large producer can frequently get special rates. Car, storage and shipping facilities are given to the large producers, that the small one must pay for and sometimes cannot get by paying for. The difference of rates between carloads and fractional carloads is to the constant business disadvantage of the small producer. The large producer gets free transportation frequently, the small one never. Most serious of all, the rates of transportation for the distinctively small farm products, butter, eggs, poultry, vegetables and fruit, which bring higher prices per unit than the stables, are such that, so far as the producer is concerned, they are no more profitable. The extent and value of farm improvements, averaged to the acre of farm, are, as a rule, inversely proportional to the total of the acreage. Small farms have several times the amount to the acre that the large farms have. Personal property appurtenant to the farms has the same acre relation. The acre of the small farm is thus burdened with a heavier flat investment than the acre of the large farm, and is taxed annually on that excess of burden.

The direct tax on land determined by its acre assessment can be made, and is more often than otherwise made to favor the large landholder. Each acre of the small landholding has absolutely a larger burden of capitation taxes, poll, than the acre of the large landholding, and absolutely a larger voluntary tax for the support of churches and semi-public institutions, and for fees and charges to public officers. The direct farm cost of production of staples is less per unit on a large landholding than on a small one, simply because the labor is cheaper.

No one of the preceding differences is very many dollars in itself, or very many cents in acre charge, but the aggregate of them all is large. It is distinctly to the disadvantage of the small landholder. Comparing the acre cost of production, taking all these items into account, there is a much smaller margin of acre profit for the small landholding than for the large landholding. And it is possible for a depression of sale values permanently, or for a temporary fluctuation even, to wipe out entirely the margin of acre profit for the small landholding, and still leave a margin of acre profit for the large landholding. This, in fact, is exactly what has been happening during the last fifteen years. The margin of profit for the acre in small landholdings has become entirely wiped out or so nearly so that the farming of small landholdings has become surely unprofitable, and as a logical and business necessity they have become undesirable. The margin of profit for the acre of large landholdings has been materially cut down, but the large landholders have maintained, or tried to maintain, their aggregate net income by increasing the number of acres from which to draw it.

It is this last tendency that Mr. Mills has observed in the statistics, and which, utterly out of touch with the men who own and work, he calls the desire to own land for its security as an investment and as a basis for loans. In reality the tendency is the expression of the instinct of self-preservation, the desire to survive by the line of least resistance against conditions becoming more and more adverse. That this tendency persists is due to the fact that the larger landholdings have or have had surplus incomes that can be applied to increase acreage even when the small farm becomes unprofitable. The small farm, unprofitable by itself, becomes profitable as part of the large farm simply because the load of its occupancy by the small landholder is taken off.

The primary incentive to the acquirement of wild land is the anticipation of profit through a rise in value, this rise in value being what is termed the unearned increment. It is the increase due to the development or anticipated development of the earning power in excess of current interest on the primary investment, being the capitalization of

that excess of income at current interest. In farming lands the amount of this increase is of necessity dependent on the character of culture and improvement possible and on location with reference to centres of trade and population and channels of communication. Soil and climate determine the most desirable kind of product for the land, and on its mean annual profit is established its basis of value. Here in California the product has been wheat. An examination of land values anywhere in the wheat-growing sections will show them based almost exclusively on the acre product of wheat, and, except in isolated districts, entirely independent of the cost of transportation or distance from centres of trade and population. The values thus determined twenty and more years ago have been fairly constant as the rate of current interest has been steadily decreasing, and as fluctuations in the sale value of wheat were practically compensated to the producer by the flexibility of the freight rates to the markets of Europe. The primary purchase price per acre being very small, wheat productions gave incomes that were interest on sums several times the flat investment. It was not uncommon for the first crop to pay back the cost of land and of all the improvements.

The minor farm products having the local market free from the competition of the surplus production of the East were also very profitable. The limit of value for these lands was rapidly reached, and for many years past their desirability came to depend wholly on the amount and certainty of their net income-producing power. This, however, instead of remaining constant, has decreased so much that the consolidation of the small farms with the adjacent large ones has been forced. The decreasing current interest rate, by maintaining the exchange value of the land, has operated to conceal the cause. So, too, has the anticipation of the development of an increased earning power through a change of production. The business results of farm culture during 1893 and 1894 have swept away illusions, and the cause of our permanent industrial and business depression is clearly in evidence. Land monopoly and decreasing population are simply effects, the ultimate and worst effects, of the cause of that industrial and business depression.

It is people who make a country. It is the possibility and profit of production that attracts people. That kind of production which attracts and supports the largest number of people is the most desirable. Wealth is the net gain of production over consumption, established into relatively imperishable, but convertible, products or natural things. No kind of production which will not give a net gain over its consumption, which will not produce wealth, will attract people. It will not make a country. Mr. Mills' paper on " Large Landholdings " is the first published recognition by any official of the Southern Pacific Company, that

the net gain of production over its consumption is disappearing for California producers; that their lands under present conditions are not wealth-creating; that they no longer attract people; that, in fact, people are leaving them.

Mr. Mills finds population decreasing, and with it the acre production of the land. He finds acre railroad earnings are decreasing, and has made a partial discovery of the relation between population, acre production, and acre railroad earnings. In a published letter to Mr. Huntington he makes public the fact that wheat gives only a sixth of a ton of freight to the acre, and a short haul at a low rate; whereas fruit, another product of the soil, gives a carload of freight to the acre, and a long haul at a high rate. Though he does not state it, it is an obvious conclusion that the exchange commodities for these products have a like ratio of earning to the railroad, and with passenger traffic the ratio is even greater.

Mr. Mills clearly sees that conditions so disastrous to the best interests of society and the well-being of the State—and to the railroad—must be changed. He clearly sees that more people and smaller landholdings will accomplish the desired change.

As a means of getting more people in the country, and inducing them to cultivate the soil, the simple cutting-up and sale of the large landholdings is no inducement, and cannot be a success. As a matter of fact, the small tracts can be had now, but the desire to get them does not exist to any marked degree. Small landholding must first be made safely profitable before it can be considered desirable. To be made safely profitable the economy of production must be changed in the direction of materially cheaper cost to the producer.

The sale value of our great staple, wheat, is not determined by the production of California, but by the demand in Liverpool, and the sale value is fixed there. The sale value at the point of export in California, tide water in the Bay of San Francisco, is the Liverpool value less freight, interest and insurance. It is with this sale value at point of export that the California producer is concerned, and with the items and amount of the cost of production to that point. These items of cost of production are, first, the farm cost, which, on the authority of the State Board of Agriculture, is half a cent a pound under conditions of large acre yield on the very largest landholdings, and which is certainly three-fourths of a cent under the average conditions of acre yield and area of land ownership; and second, the freight and incidental charges of transportation.

The first of these items, the farm cost, cannot be lessened; if anything, economy has gone too far in the attempt. If the cost of production is to be lessened, it must be in the second item, the freight, more

specifically the railroad freight, wherever the railroad is a carrier. As sale values are at the present time, the railroad freight takes a portion amounting to a third, and more from wheat produced in the upper San Joaquin Valley. So much, in fact, that the sale value does not even recoup to the producer his farm cost alone, and for the use of the land it pays nothing. If small landholding is to be made safely profitable, small farm products must have the advantage in the local markets, which their nearness legitimately entitles them to. This advantage can be assured if transportation charges be made on the basis of the service rendered only. The present condition is such that the Eastern producer is admitted to the market on more favorable terms as to freight charges than the local producer. If small landholding is to be made safely profitable, railroad transportation charges must not discriminate between classes of production. Also, must the transportation of products, as between large and small producers, be placed on an exact equality? Finally, such transportation rates should be made on the distinctively small landholding products exported from the State as to insure a profit to the producer, despite the ordinary fluctuations and uncertainties of the market. To illustrate this last, take the case of a 25-pound box of green peaches (of Placer County), a distinctively small farm product. The cost of production to the point of consumption is made up of the following items:

1. The farm cost, cultivation, pruning, picking fruit, packing, and transportation to the railroad station	$0.135
2. Water for irrigation	.01
3. Box	.07
4. Paper for wrapping	.01
5. Putting into car	.025
6. Railroad freight, including ventilator car (if with refrigerator car $0.156 additional)	.47
7. Selling commission, 7 per cent.	.05
Total cost of production at consuming point	$0.77

That is, the box of peaches must sell for 77 cents to just repay all the cost of production. If more than 77 cents is received, 93 per cent. of the extra amount is profit, which is the earning of the capital invested in the land and trees. This extra amount is now so small that a slight depression in the market sale value, or a slight impairment of quality incident to the long transportation, makes the fruit produce a loss to the grower. A margin over the cost of production of 15 cents (which is more than the average for the last two years) on a production of 500 boxes to the acre for 10 acres, amounts to $750. In addition to this, $0.135 a box, $675 for 10 acres, the farm cost of production, comes back in the sales return. Of this last amount $150 will be the cost of

keeping a horse, and $250 wages and board of extra labor, picking and packing, leaving $275 for the wages of the owner. This, added to the $750, makes a total net return to the grower of $1,025 per annum.

The same mechanical skill and intelligence required for the successful growing of fruit would bring to its possessor as wages, without capital investment, in other forms of industry, not less than $3 a day, amounting to $900 per annum. The difference between this amount and $1,025, $125 is, in reality, the total gross income of his capital of land and trees, from which must still be deducted taxes and other charges incident to the possession of property, leaving certainly not more than $100 as the net income of his investment of 10 acres of land and orchard. The ultimate valuation of that land and improvements per acre, based on this amount of net income, money being worth 10 per cent., is only $100, which just balances the actual cost of the trees brought to bearing, and leaves nothing to represent the value of the land. Of course the income of $1,025 is, with other things, an inducement for labor, but it is absolutely none for the investment of capital in ten-acre landholdings.

As a fact, in this year of 1894, the profit margin is practically wiped out, and growers will be fortunate who realize sufficient to repay the farm cost of production. Undesirable as is this present condition, the outlook for the future is even more unpromising. The inevitable increase in production of fruit must find an increase in consumption to absorb it. This means a market among classes of people that the fruit does not now reach, and to be taken by them the mean sale value must be lower for the whole production to meet their ability to pay.

The future sale value is then certainly less than the present one, just as the present sale value is less than that of five years ago. This inevitable decrease in sale value can be compensated for and the margin for profit increased in only one way. The cost of production must be reduced, and in absolute amount a considerable sum. An examination of the several items of the cost of production given for the box of peaches will show only one large enough in amount, the freight, to be materially reduced. This, as it now stands, is 61 per cent. of the total, where the highest other single item, the box, is only 9 per cent. It is clearly evident that unless the freight item of cost be materially reduced, small landholdings producing fruit cannot be made safely profitable, and those that now exist will be absorbed by the larger landholdings.

The peach has been taken as the extreme favorable case for the small landholder. It is the peach that by the profits of its production a few years since has developed the unearned increment of Northern California lands, just as it has been the orange that has done a like service for the Southern California lands. It has been the development

of this unearned increment by the profits of the first in the industry which has made small landholdings desirable. In amount this unearned increment has exceeded many times the basis value of the wild land, or the land used for staple production.

Take Placer County, concerning which I am best advised as to the facts, for an example. In it, in 1891, there were just 6,000 acres of irrigated land in about three-fourths of its maximum possible production, that is, it was not all in full bearing. The figures taken from the assessment roll show an appreciation in value, such a development of the unearned increment as to seem hardly credible. The following figures are made from the assessment roll of 1891, and include the exclusively agricultural land lying below an elevation of 1,500 feet, being all of the county west of a line drawn north and south two miles east of Auburn. Mining claims and towns are not included. The landholdings for more effective comparison are segregated into valley or plain lands, part of the Sacramento Valley; unirrigated foothill farms and irrigated foothill farms.

VALLEY LANDS.

Number of farms assessed	225
Total acreage	143,386
Average acreage per farm	637
Total assessed valuation of land	$1,544,703
Average assessment of land per acre	10.77
Total assessed valuation of improvements	153,179
Average per acre	1.06
Total land and improvements	1,697,882
Average per acre	11.83

UNIRRIGATED FOOTHILL FARMS.

Number of farms assessed	599
Total acreage	85,313
Average acreage	142
Total assessed valuation of land	$1,075,956
Average valuation per acre	12.61
Total assessments of improvements	161,684
Average per acre	1.90
Total land and improvements	1,237,940
Average per acre	14.51

IRRIGATED FOOTHILL FARMS.

Number of farms assessed	328
Total acreage	30,272
Average per farm (acres)	92
Average per farm irrigated (acres)	18.4
Total assessed valuation of land	$715,501
Average per acre	23.63
Total assessed valuation of improvements	334,953
Average per acre	11.06
Total land and improvements	1,050,454
Average per acre	34.69

From these figures, and those of actual sales, the value of the unearned increment of the actually irrigated and bearing foothill lands is $280 an acre, fourteen times the mean sale value of contiguous unwatered land in the foothills, and fifteen times the mean sale value of the valley wheat lands. The sale figures show $100 an acre additional as the unearned increment of the bearing trees. The aggregate of these two for the 6,000 acres of irrigated land is $3,800,000, all of which, and another undetermined amount in town real estate and improvements, is the earning power created by large net earnings from the sale of the small farm product, fruit. The actual amount of this unearned increment appearing on the assessment roll for the year 1891 was $970,000. But the large net earnings of the land on which these values were based were not the net earnings of 1891, but of preceding years. In 1892 there was only a small profit margin, as closely as it can be estimated about 15 cents to the 25-pound box of peaches. In 1893 even that practically disappeared, and in this year of 1894 it has more than disappeared. Values remain, just as they do for the wheat lands, but, just as in the case of the wheat lands, they are only a survival, what was, not what is. They were wealth-producing, they are not now. The possessors cling to them only in the hope of realizing on them through a sale to some outsider who is not expert enough to comprehend the real condition.

The statistical figures already given, and some others here stated, furnish the basis for conclusions relevant to society as between conditions of large and small landholding, which are equally instructive with those presented in Mr. Mills' paper. The 6,000 acres of fruit farm lands in 1891 directly supported a population of not less than 1,500, and town population adjacent of 1,000, in addition contributing to the support of another distant population engaged in box- and paper-making. The 85,000 acres of unirrigated foothill farms did not maintain directly and indirectly more than 1,100 people. The 143,386 acres of plain farms furnished support for only 1,500 people. The density of the supported population is at the rate of 265 to the square mile for the small farm fruit area, and only seven to the square mile for the large farm areas. The latter has been for years decreasing in population, one town, Sheridan, has practically disappeared in the last ten years, and another, Roseville, is tending the same way.

On the small fruit farms are comfortable modern dwellings and conveniences, and the surroundings are made attractive, indicating leisure and the accumulation of wealth, or the anticipation of its accumulation. School-houses and churches are cheerful-looking buildings, and are well supported. The reverse of these facts is the rule of the other farms and their localities. While mortgages that cannot be accounted for, as the unpaid balance of purchase price of the land, expenditure for improve-

ments, or capital employed in other occupations, only amount to 12 per cent. of the assessed valuation of the improvements alone on the small fruit farms; on the valley farms these mortgages amount to the entire sum of assessment of improvements, and to 9 per cent. of the assessment of the land besides. The fruit growers are constant travelers by rail, the others are not. The 6,000 acres of fruit farms furnished, in 1891, 1,500 carloads of outgoing products, and 500 of incoming supplies, more than these figures rather than less. The 85,000 acres of other foothill farm, and the 143,386 acres of valley farm, during the same year, furnished in outgoing freight not over 500 carloads, and in incoming not over 150. The first pay high rates on long hauls, and the second pay for short hauls at low rates.

Placer County in itself shows the undesirable tendency toward the growth of large landholdings, and in itself as well as the desirable tendency toward the multiplication of small landholdings. The very closeness of contact of the two forces contrasts them the stronger. The causes that have been operating to make business failures of one class of agricultural industry, the causes that have operated to make business successes of another, are alike comprehensible and measurable. The relation of these two classes of causes to transportation is clearly defined. Nowhere is more clearly established the fact that the underlying value of a railroad is not in its track and rolling stock, but in its people and its country.

Now, if the wealth-developing power, which has made small landholdings desirable, can be maintained instead of disappearing, population will increase instead of decrease, the extension of large landholding will be checked, and ultimately turned the other way. On precisely even terms the small landholder will beat the large landholder in the economy of production, and will ultimately displace him. It is the certainty of the maintenance of the developed values, and the certainty of even terms between individuals, that is wanting. Neither exist. The decreased margin between the cost of production and the sale value of the small farm products has wiped out the possibility of profit, and with it the wealth development of the small landholdings. This is realized by the small landholders, and finds expression in efforts to reduce the cost of production along the line of least resistance. Labor has been reduced in remuneration till its compensation is so small that further yielding in that direction is impossible. The cost of packages has been pushed down to the unyielding point. No item of cost has not been too small not to have been magnified in relative importance and efforts made to reduce it. Taxation has been tinkered with, and precisely the wrong thing done. Irrigation water, which takes the least of the product and gives most in return, has been made the scapegoat for failure of profit.

These misdirected efforts to reduce the cost of production, misdirected because the aggregate of all of the possible gains is insignificant as compared with what is necessary, have created an uncertainty as to the future in the minds of those who should be best able to forecast it, that extends to all business enterprises that otherwise would be put in operation. Capital will not invest in colonization, irrigation or manufacturing in the face of this uncertainty. The element of security is wanting. It is the real reason why population and small landholdings are decreasing instead of increasing, for the small owner of wealth is just as anxious as the large owner to have security that he shall keep what he has gathered together.

The present industrial and trade condition in California is simply the logical resultant of the persistence for the last twenty-five years of the reckless business policy of its great distributive agency, the Southern Pacific Company. This policy had its inception at the close of the time and business methods when the production of California was wealth itself, gold dug out of the earth, not obtained as the difference of exchanges of consumable products. Taking all of this gold it could, it still left some to the producer, and the ultimate effect of its persistence was not foreshadowed. Persisting in its policy after the wealth-producing power of California became less in the gold taken direct from the earth, and more in the difference of exchanges of its sun and soil products, the amount taken has closer and closer approached the whole of this difference. The fruit production development, commencing ten years ago, was to the Southern Pacific Company like the old yield of the gold mines come back again. To the producers, the people, who brought that gold in from the inside, what the Southern Pacific took while waiting for their trees to bear was a part of their investment of capital, not a charge against their gross income, which would wipe out the possibility of their being any net income. The ultimate effect was not foreshadowed to these fresh producers, the old ones drained, remained silent, perhaps they, too, might find fresh producers. It has been the old fable of the goose which laid golden eggs over again, only California is a bigger goose than the one in the fable.

In this year of 1894 the logical resultant of the persistence of the reckless business policy of the Southern Pacific Company is an actuality, a fact. The earning power of some of the most sun-blest land on the earth has been pushed down below the profit point, and the land made undesirable, population has decreased, wealth has disappeared. That the business and industrial fabric stands at all is only because it is a habit, its real stability is that of a soapbubble, of wind.

In conclusion, if California is not to be a failure, action is an imperative necessity. Great as are her natural resources, the wealth they

have produced so far, and what is left of their wealth-creating power, has been made an appurtenance of the Southern Pacific Company. Not producing anything, merely distributive of the energy of producers, as its share for that distribution it is taking so much that there is nothing left for the producers. The remedy for this condition is obvious and simple. The Southern Pacific Company must take less of the production than it has been taking, not a little less, but a great deal less. It must take less, voluntarily if it will, if not it must take less by being made to. It is either that remedy, or else———

There is just one other stage of California landholding. Mr. Mills does not state it, but it is just the same inevitable under the persistence of existing conditions. The State will have just one land monopolist—the Southern Pacific Company.

DISCUSSION.

W. G. Curtis (Member Tech. Sec.).—The particular points of the subject-matter covered by this discussion relate to the question as to whether or not California railway rates tend to promote land monopoly, and to the effect of the policy governing railway rates upon the growth of Placer County.

I am glad the Technical Society thinks it proper to admit subjects appertaining to the questions treated in Mr. Dunn's paper.* In its membership the Society embraces a wide range of industrial activity, and there is no good reason why we should not deliberate upon social questions, and concern ourselves somewhat with the problems of political economy, as well as with the physical sciences.

The principle of inertia, as affecting social progress, is akin to the operations of the law in physical nature. The industrial development of a country, once started in the wrong direction, can be turned therefrom only by the application of some force, which may, and in times of peace, is very likely to be a long time in producing visible results.

To begin with a little familiar history, the first reference to the region now covered by the State of California, found by historians, is in the old Spanish records of a report transmitted by Cortez to Emperor Charles V. of Spain, in the year 1524, wherein it is represented to be "an island rich in pearls and gold." The peninsula of California, now known as Lower California, was discovered by Fortuno Ximenes during his expedition in Cortez's ship, "La Concepcion," in 1534. The name "California" seems to have been first applied by Cortez, who found it in one of the romances of chivalry written about the year 1500, wherein it

* On same subject read before the Society, September 7, 1894.

was used as the designation of an island "on the right hand of the Indies, very near the terrestrial paradise."

The Spanish voyagers, Cabrillo and Ferrelo, sailed along the entire Coast of California in the years 1542–43. Sir Francis Drake, coasting the eastern shore of the Pacific searching for the much desired northern passage, supposed to connect the two great oceans, landed at Drake's Bay in 1579. The country was then inhabited by a small number of Indians, probably not exceeding 10,000, living in the hunting and fishing stage of economic development.

Early in the eighteenth century there is supposed to have been some expedition to the southern part of California by the Jesuits, but no systematic settlement of the country was accomplished until the year 1769, when the Mission of San Diego, in the southwestern corner of the State, was founded by the Franciscan Monks. The Mission of Monterey was established a year later, and abont a year after this the Mission Dolores was founded in this city.

In 1805 the population of California, as registered at nineteen missions and some half dozen villages, was stated to be 22,800, of which 20,600 were native Indians. In 1826 the total population was stated in the old church records as 24,614.

While the old fathers, almost simultaneously with the founding of the mission churches, began on a small scale the practice of irrigation, at once planted many of the present characteristic fruits of the State, and otherwise demonstrated the fertile qualities of the land, the country was regarded by the Mexicans and Spanish settlers as suited chiefly for cattle-raising, and when, in 1848, by the treaty of Guadalupe Hidalgo, California was ceded to the Uniten States, the latter took the country pretty much at the Mexican estimate, as suited only for pastoral pursuits.

Almost simultaneously with this cession of California to the United States, gold was discovered, and a year later thousands of gold-seekers were prospecting along the ravines and hillsides, eager in their search for gold, but with no thought of any other productive capability of the State than cattle and precious metals. Consequent upon this view, which prevailed for many years after the advent of the gold-seekers (and the writer well remembers in Mr. Dunn's part of the country, as late as 1864, the prevailing sentiment among the people was that sooner or later the mines would be exhausted and the miners would return to their Eastern homes, leaving the country once more in the possession of the Mexicans and Indians), our Government agreed to sustain the titles to Spanish grants, some 350 in number, covering an aggregate area of over 8,700,000 acres, or from 25 per cent. to 30 per cent. of what the best authorities set down as the total arable area of the State. These 8,700,000 acres cover the best valley lands of California.

A few far-sighted Americans, deserting the ranks of the miners and affiliating with the Spanish grant owners, found many ways of extending their landed possessions over Government land and railroad grants, and thus keeping up the holding of land in great tracks. The salient facts in this connection are well set forth in the paper referred to by Mr. Dunn. As a result of this, when it became apparent, even to the dullest mind, that California was not only a pastoral country, not only a mining country, but a region of almost unbounded possibilities for the production of all the fruits grown in the temperate and semi-tropic regions of the world; when it was realized that the occasional peach-tree, apple-tree and grape vine, successfully planted here and there in front of the miners' cabins in the foothills, as well as the fig, the orange, the olive, and other semi-tropic trees, thriftily growing around the old mission churches, all proclaimed the capability of the surrounding country to abundantly produce these and similar fruits; and when it was demonstrated that nearly everywhere in the State farms of from 10 to 160 acres could be profitably cultivated for fruit raising, the greatest obstacle standing in the way was the large landholder, wedded to the idea that farming operations in this State are feasible only on a great scale; the cattle-raiser having his broad Spanish grants for pasturage and the grain farmer measuring his fields by the thousands of acres.

Fortunately for Placer County and many other localities in the State, the seeker after large landholdings did not much value the foothills, so when the time came for beating the spear of the miner into the pruning-hook of the farmer, lands lying along the lower mountain slopes could still be acquired, in small tracks, from the Government and other sources, for horticultural operations. According to "Resources of California," published last year under approval of the Governor, the shipments of fruit for 1892 from Placer County aggregated 1,125 carloads. The same publication contains the statement: "One-fifth of the deciduous fresh fruit shipments from California to the East in 1892 was made from Placer County—mainly from a section 12 miles long and 5 miles wide." The great capabilities of the foothill regions of California are apparent when we reflect that along the westerly flank of the Sierras, under 4,000 feet altitude, between Redding on the north and Bakersfield on the south, their is a belt of arable foothills, over 400 miles long, all in greater or less degree similarly capable of producing fruit.

While the population in some of the agricultural counties, where large landholdings prevail, has diminished, it is also the case with several of the mining counties, which are situated at such a distance from railway transportation that they have not developed their agricultural resources. Placer County, however, stands in the front rank of the old

mining counties which have steadily advanced, the population and assessed valuation of real and personal property from 1870 to 1890 being as follows:

Year.	Population.	Assessed value real and personal property.
1870	11,357	$4,063,639 00
1880	14,232	5,774,860 00
1890	15,101	10,118,060 00

The Hon. Jeremiah Rusk, Secretary of Agriculture, doubtless having just such localities as Placer County in mind, said, after his return East from a visit to this Coast:

"The enormous yield of the vineyards and orchards are facts which are but little known to the majority of the people, and but few even of those who know them realize the full meaning. To the Eastern man who has tilled the farms of twenty and forty acres that his father tilled before him, the farms of this great State (California) are as legends of fairyland, and when told that, with the same energy he expends on his forty acres, he can farm in California four times forty acres, he becomes incredulous—he cannot imagine such farms as I have seen in that State."

Mr. Dunn puts the query: "Are decreasing population and increasing land monopoly the cause of the condition of fares and freights, or is it not the fact that the condition of fares and freights is the cause of decreasing population and increasing land monopoly?" When contrasted with the Mississippi Valley States, where, at the commencement of the development of agricultural resources, land was owned by the Government, and could be obtained at the minimum price, it is seen from the foregoing, that when the agricultural and horticultural possibilities of California were perceived the land was already monopolized. I am unable to see where anything connected with, or dependent upon, railroad transportation runs in the direction of favoring the aggregation of land into large holdings. Before the railroad was constructed, and the cultivation of fruit in California for sale beyond its borders was made possible by affording the means to reach the market, in competition with local grown similar productions 2,500 to 3,000 miles away, practically the only industries connected with the use of the soil were cattle-raising and grain-growing. As to the transportation of grain, which in general reaches the ultimate market by ocean carriers, the railroads of California can have but little to do beyond moving it from the fields to tidewater. Sacramento Valley, the principal section of the country treated of in Mr. W. H. Mills' paper of two years ago, referred to by Mr. Dunn, has a navigable river running throughout the Valley, open at all seasons of the year. This is one of the greatest grain-producing sections of the State. It is not possible that the railroad rates for transportation of grain to tidewater from this region have

been excessive, otherwise the shipments would have been made upon the navigable river; the railroad, if unreasonable, would have got nothing to haul. The fact that it has obtained its full share of this traffic is well known, and must be taken as *prima facie* evidence of the reasonableness of its rates.

Mr. Dunn says the income he figures on ten acres may be "an inducement for labor, but it is absolutely none for the investment of capital in ten-acre landholdings." I apprehend that California's need is not so much to attract the capitalist into fruit-growing as to develop it for the small farm-holders who reside with their families on the land. Mr. Dunn has selected ten acres as his typical small fruit landholding. Possibly such a farm is too small to be reasonably profitable; then why not try twenty acres? Mr. Mills and his friends do not insist that ten acres shall be the limit; their contention is, rather, that the holding of lands, as, for example, in one hundred 16,000-acre farms in the Sacramento Valley is not as good for the State of California as if the same land was divided up into small holdings. Mr. Mills, as I remember, comments on the possibilities of fifty-acre farms, but in stating his conclusions takes 100 acres and computes that 100 landholders whose holdings embrace 1,654,000 acres of land displace 16,540 families, each having 100 acres of land. If these 16,000 families should occupy the land now held by the 100 men, and turn their industries toward the production of grain, they would control the railroad rates, if necessary, by shipping their products out by river. Should they raise fruit and seek a market over in the Eastern States, the railroad companies could be depended upon, if necessary to profitably market the product, to continue as they are now doing and move it to market at the cost of carrying. More than this the railroads cannot do, and under such conditions they cannot be justly charged with retarding the development of the country. With land monopoly established, the lowering of railroad rates (in the Sacramento Valley for example) would only tend to perpetuate such monopoly, because transportation could be had by these large landholders free for the asking, their large-scale operations would be still more profitable, and they would be more disinclined to cut up their land and offer it for sale in small parcels.

The tone of Mr. Dunn's letter is in line with the popular fallacy that somehow, by some means, the Southern Pacific Company has managed to hold up its rates and its earnings, while the producers whom it serves are becoming slowly impoverished. As an indication of the facts, let us look at the course of the Southern Pacific System's average rates on commercial freight from 1872 up to the present time:

Year.	Av. rate per ton per mile (cents).	Av. rate passenger per mile (cents).
1872	3.66	3.83
1880	2.68	3.16
1888	1.93	2.21
1893	1.57	2.11
1894 (first seven months)	1.32	1.80

These little figures, indicating that the current passenger and freight rates are both less than half the rates in 1872, when times were certainly good in California, are not very impressive, but if we apply the rates of 1872 to the commercial freight and passenger traffic of the Southern Pacific Company's Pacific Coast lines in 1893, we find that, at the 1872 rates, the earnings for 1893 would have been over $35,000,000 greater than they actually were, and had even the rates for 1880 been earned on the traffic movement of 1893, the earnings would have been nearly $19,500,000 more than actually taken in by the Company. So far, then, from fixing its rates and standing to them, regardless of the necessities of its patrons, the Southern Pacific Company has, by the adjustment of its operations to the commercial conditions and necessities of the Pacific Coast, lowered its rates until it has, of its earning power, given up to its patrons, even as compared with 1880, a period when the fruit industry was just beginning to become a factor in transportation, nearly $20,000,000 per year.

The fruit from Placer County starts East over the Central Pacific line and is delivered to connecting lines at Ogden. The division of the through rates to Eastern markets being made between all of the lines on a mileage basis, the Central Pacific conceding a division on this basis in order to bring the Eastern connecting lines to an agreement on the through rates demanded by the fruit shippers, though, by reason of the greater physical obstacles to be overcome and its other operating disadvantages, the Central line is entitled to a larger proportion of the rate. It concedes to its Eastern connections the division of the through rates to Eastern points on about an even mileage basis, but before starting on its Eastern journeys the freight is lifted on the Central line 7,000 feet above the sea, the expenditure of power requisite to move a ton of weight to the summit of the Sierras being equivalent to the power necessary to move the same ton 450 miles on a level grade. The cost of fuel on the Central Pacific line in California, delivered on tenders, averages $4.80 per ton, as against $1.57 per ton on the Union Pacific, and from $1.36 to $1.82 per ton on the various lines from Council Bluffs to Chicago.

The Interstate Commerce Commission, under the rule established by them, and which unquestionably produces results as near the truth as possible, find and report the cost, for operating expenses only, of

moving one ton of freight one mile on the Pacific System lines of the Southern Pacific Company (averaging the valley levels with the steep mountain gradients) to be from $\frac{90}{100}$ of a cent to 1.02 cents per ton per mile.

The average rate per ton per mile for transportation of California orchard and vineyard products to market in the Eastern States does not now exceed $\frac{9}{10}$ of a cent per ton per mile, a sum merely equal to the average cost of operation for maintenance of way and structures, conducting transportation, etc., contributing nothing, however, available for the payment of taxes, interest upon the bonded debt, and other necessary and legitimate fixed charges.

While we are accustomed to hear the railroads denounced for not paying their taxes, I find it to be a fact that the Southern Pacific lines have paid into the State and County treasuries of California a little over $8,000,000 in payment of their taxes for the past fourteen years. In the same fourteen years the sum total received by the Southern Pacific Company for hauling (not only through California, but also through Nevada and Utah, and through Arizona and New Mexico) fruit shipped from California to the Eastern market has been for

Green deciduous fruits	$3.710,221 00
Dried fruits	1.704.593 00
Canned fruits	1,982,273 00
Or a total for all deciduous fruits of	$7.397,087 00

say in round numbers $7,500,000, or a half million dollars less than the amount of California taxes paid in the same period.

Another fact of interest to Californians is this: An investigation made about three years ago by one of the officers of the Southern Pacific Company developed a condition which doubtless remains true up to the present time, namely, that by reason of the fact that there is no lumber or other materials needed for current repairs of the railroads in Arizona, New Mexico, Nevada and Utah, large quantities of supplies required for the maintenance and operation of the Southern Pacific roads in these States and Territories are purchased from California producers, dealers and traders, the total amount of such purchases exceeding the Southern Pacific earnings from the strictly local movement of freight and passengers within the State of California.

The Central and Southern Pacific lines have pioneered in the building of railroads in advance of industrial development, and must be content to await results, which are sure to follow, bringing the full measure of prosperity to all interests. In the meantime, they must earn for the capital invested fair rates of interest, must pay for the materials and supplies necessary for the maintenance of their property, and

must pay the men whose services are necessary for its operation. The railroads are carrying at bedrock rates, and if it is true that the fruit-growers are also in distress, it is time to look in some other direction than a further lowering of transportation charges for a means of restoring living prices to both the producers and railroad companies. The middlemen are useful, but it is well to inquire whether they are not making too much profit when we find, as was recently ascertained to be the fact, that dried fruit sold by the California producer at six cents a pound, hauled over by the Southern Pacific and its connecting lines to Minneapolis, for a trifle over a cent a pound, is sold to consumers at the latter place for fifteen cents per pound. In such cases it does not appear that either the producers or the railroad companies are getting what is fairly their due. It is not likely that the middlemen and dealers in general are dividing up profits at this rate, but if it is true that, as a rule, they are taking more than their share, the obvious remedy is the adoption of some means for bringing the producer and consumer closer together. Fruit exchanges, such as appear to be in successful operation in Fresno, Santa Clara and Riverside Counties, indicate a step forward in the right direction.

The existing method of preserving the fruit against decay, in transit, are expensive, not only to the shippers, but to the railroad companies obliged to use up their power in hauling the great dead, or non-paying, weight of refrigerator cars; but there are hopeful possibilities of a reduction in this expense. Experiments have recently been made for producing the refrigeration for the preservation of fruit in cars by the expansion of compressed air, or by supplying into the cars air which has been sterilized by an admixture of antiseptic gases. The success of these experiments would effect a great reduction in the cost of preserving fruit *en route* to the East.

The California small farm owners are not quite living up to their opportunities for supplying our local markets. That there is room for a profitable development in this direction is evidenced by the fact that last year there was brought, by rail lines, from the East into the Pacific Coast States, practically all of it coming into California, 39,945,000 pounds, or about 2,000 ten-ton carloads, of stock-farm and poultry-yard products, in their natural state or manufactured into staple commodities; over 36,000,000 pounds of this tonnage was composed of articles of food, such as butter, cheese, poultry, meats in bulk, lard, eggs, condensed milk, etc.; the shipment of eggs alone amounting to 5,500,000 pounds. In adtion to this, in 1893, there was shipped from the Eastern States and foreign countries into California, by rail over 13,000,000 pounds, and by sea about 70,000 packages of canned goods, including fish, oysters, canned meats, canned corn, and other vegetables. Undoubtedly articles

corresponding at least to one-half these goods are now, or could be, produced in California.

Of other articles annually shipped to the Pacific Coast from Eastern States, or imported from foreign countries, which might be supplied by California farmers, may be noted over 9,000,000 pounds, shipped by rail, and about 900 packages, by sea, of alcohol and spirits; over 1,250,000 pounds by rail, and about 1,500 packages by sea, of dried fruit and dried currants; nearly 1,250,000 pounds of oats; over 1,000,000 pounds of pickles, preserves and jellies; over 3,700,000 pounds of cornmeal and oatmeal; nearly 1,250,000 pounds of farm and garden seeds; nearly 2,000,000 pounds by rail, and over 11,000 packages by sea, of wines; nearly 1,500,000 pounds of broom corn and brooms; over 60,000 pounds, by rail, and about 14,000 packages, by sea, of olive and salad oil, not to mention "coals to Newcastle" in the shape of over 9,000,000 pounds, by rail, and 1,000 packages by sea, of flour.

In the way of other things that California can likely produce for the supply of local wants and the general markets of the world, are textile grasses, flax, hemp, jute, and fibrous vegetable substances other than cotton. The value of these raw materials and articles manufactured therefrom, imported into the United States for the year ending June 30, 1893, was, in round numbers, $49,500,000.

California is still in the experimental stages of its development, and when the supply of any one of its peculiar productions approaches the demand of existing markets, the profits of the industry, pending the building up of new markets, are likely to be uncertain. The railroad companies cannot always stand in the breach between the producer and the consumer in such a way as to always insure profits to the former. When they sacrifice their profits to the necessities of their patrons, get down with them to a cost basis and move any commodity for the mere cost of carrying, they cannot be justly asked to go further. Notwithstanding all that has been said to the contrary, the fact remains that the railroad companies of this State have consistently shown by their acts that they are working in full sympathy with the industrial interests of the communities they serve.

Knowing their integrity of purpose in this direction, the managing officers of the Southern Pacific Company are well pleased to accept every challenge to fair discussion of their business relations to other people, realizing that the facts, fairly stated, lead to no other conclusions than that their business methods are just and reasonable.

NOTES ON THE CONSTRUCTION OF THE EAST RIVER GAS TUNNEL.

By Walton I. Aims, C.E.

[Read before the Boston Society of Civil Engineers, April 17, 1895.]

During 1891 and 1892 the East River Gas Co., of Long Island City, a corporation with works situated on the Long Island shore of the East River, obtained from the New York State Legislature a new charter, and such necessary legislation as to permit the extension of their mains across the East River into the city of New York. This project had many important features to recommend it. New York, with an average of 45,000 inhabitants to the square mile, presents, to a gas enterprise, the favorable conditions of a much concentrated population. The citizens have long been strenuous in their efforts to abate all nuisances surrounding their dwellings, and they are quick to appreciate improvements in that direction. As the manufacture of gas in the heart of the city has been found very objectionable, the location of such works outside of the city is an important consideration. For another reason, the location of the works of the East River Gas Co. was most happy; for while so situated as to derive the benefits of the enormous difference in value between city and suburban real estate, yet these works are directly opposite the heart of the residential district of New York and but half a mile distant from the city. Here twelve acres of land had been secured for plant purposes, with a river frontage of over 800 feet, on which there is sufficient room for the erection of a plant of 50,000,000 feet daily capacity.

The most important point in this whole enterprise was how to bring the gas across the East River. The feasibility of constructing a tunnel under the river through which the gas mains might be laid was discussed, and after some preliminary surveys and examinations a route was decided upon from the works of the company at Ravenswood, Long Island City, to between 70th and 71st Streets, New York, passing under Blackwell's Island and the east and west channels of the East River. On about this line of location some eight or ten pipe soundings were made in the two river channels, all of which indicated a rock bottom; and the results of these, together with surface indications, where at both the Long Island and New York shores, as well as on Blackwell's Island, bed-rock lay exposed, led all to conclude that nothing but rock was to be encountered. On these investigations a contract was entered

into on June 25, 1892, for the construction of a supposedly rock tunnel, which the contractor guaranteed to complete by April, 1893.

Work was begun at the Ravenswood or Long Island side on June 28th by sinking a shaft about 200 feet back from the river 9 feet square, to a depth of about 148 feet below the surface; while at New York, on July 7th, a shaft of the same dimensions was started on private property fronting on 71st Street and East River, and sunk to a depth from the surface of 139 feet. In both these shafts rock was entered after about 8 feet of soil; but while the rock at New York was quite dry, at Ravenswood it proved seamy and very wet.

The tunnel-roof grade had been established at 109 feet below mean high water at the New York shaft, with a grade for drainage of one-half of one per cent. towards Ravenswood. This gave a minimum cover of 41 feet at the deepest point in the west or New York channel of the East River, where there is 70 feet of water at mean high tide. The east, or Long Island channel, is comparatively shallow, the deepest point being only 35 feet below mean high water level. The one thing feared was that fissures yielding large volumes of water might extend to the tunnel roof and largely augment the cost of pumping. The size of the tunnel section was to be 8 feet 6 inches in height by 10 feet 6 inches in width, this giving sufficient room for the laying of two 3-feet gas mains and one 4-feet main.

In the shafts, on both sides of the river, the headings were now turned. At Ravenswood the work was delayed by meeting considerable quantities of salty water, but at New York the tunnel was practically dry until towards the end of December, 1892, when, at a distance of 338 feet from the shaft, a fissure was struck yielding about a three-inch stream of salt water. The rock to within 20 feet of this point had been the regular hard New York gneiss, with a dip towards Long Island of 10° from the vertical, and a strike north and south at right angles to the direction of the tunnel. Here it gradually began to soften, becoming more and more micaceous until when about 20 feet beyond the water-bearing fissure the rock suddenly terminated, running into a vein of soft material with the same dip and strike as that of the rock.

This new material proved to be a vein, principally of decomposed feldspar, gray in color, crumbling easily, and with no perceptible grit. It still preserved a rock structure, and was perfectly dry when undisturbed. But its exposed surfaces were quickly acted upon by water which it would absorb and then wash away quite rapidly. The water-bearing fissure and this soft vein were connected; more water was also met at the junction of the rock and the soft material, and later experience proved that in passing through these soft veins water was always to be found next to the rock—a sort of water-course on both sides of the soft vein.

Had it not been for encountering this water, the tunnel might have been carried through the soft material without employing compressed air, though the prudence of attempting this might be questioned, for nothing more insures the safety of both the men and the work than compressed air in sub-aqueous tunneling.

The finding of this soft material, so unexpected, was quite a set-back to all concerned. However, it was decided to drive a small timbered drift about 4 feet wide by 6 feet high to investigate the ground ahead and find how much of this material was to be penetrated before solid rock was again met. This drift was started and driven in for about 6 feet. Meanwhile a most destructive action was going on between the water and the soft material. The water running along the face of the rock had washed out a cavity overhead in the soft ground. The walls of this cavity were gradually breaking away, and the clay-like substance falling down would close the outlet of the water into the tunnel. The water would then accumulate in this pocket, softening up fresh material on the sides until it had gained a sufficient head to burst through the dam which confined it, when it would come rushing into the tunnel, carrying with it large quantities of the softened material. These rushes were accompanied by a loud bubbling sound that quite mystified the men, which was, of course, the sound of the air displacing the water in the cavity. As soon as the pocket had emptied itself, for a time the trouble was over until with the falling of more material the outlet was again closed and the operation was repeated.

These rushes of water, with the accompanying sound of the bubbling air, soon became more and more alarming to the men. The cavity was constantly increasing in size, and extending up toward the river bed. Each recurrence would now send the men running for the shaft, by no means certain that the river had not at last made a connection with the tunnel.

All work in the small drift was abandoned, and on December 31st a bulkhead was hurriedly constructed, at the face, to prevent the threatened flooding of the shaft. Up to this time over 25 yards of material had been washed into the tunnel, all of which had come from along the rock face. With the river bed only 45 feet above the tunnel roof, there is every reason to believe that this bulkhead was put in none too soon, and a connection with the river narrowly averted. The bulkhead was well packed with hay to prevent, as much as possible, further washing of the material, and a discussion was now entered into as to the method of future procedure. The contractors were in favor of abandoning the heading and returning to the shaft, to sink to a lower level and start anew in hopes of meeting more favorable conditions at a greater depth.

There had been a somewhat similar experience on the Croton Aqueduct, where that tunnel passes under the Harlem River. Soft material had been encountered on the first established level, which proved so troublesome that after two or three unsuccessful attempts had been made to pass through it, it was finally decided to abandon the heading and return to the shaft, sinking some 150 feet deeper. On this new level nothing but rock was encountered. In the East River tunnel, however, the soft material was clearly a decomposed vein, and to what depth this decomposition might extend was unknown; so that as there were no well founded reasons, in this case, for expecting any better conditions at a lower level, it was decided to first attempt to drive the present heading, in compressed air, leaving the sinking as a later expedient should the proposed means fail.

An arrangement was made with the contractors by which the company was to share the expense of the work in soft ground. It was at this time that the writer became connected with the work, having charge of installing and conducting the compressed air operations for the Company.

To form the compressed air-working chamber, a solid brick wall or bulkhead 8 feet thick was built across the tunnel into gains in the rock about 40 feet back from the heading, and containing a cylindrical steel air-lock 6 feet in diameter and 10 feet long.

In the engine room, the 18″ x 24″ Ingersoll piston-inlet compressor, used heretofore for running the rock drills, was supplemented by a small Rand compressor, and both arranged to supply, independently, compressed air to the working chamber below. Incandescent electric lighting was introduced into the tunnel, which is almost a necessity in compressed air operations, as common illuminants produce an enormous quantity of smoke, when burning in compressed air. A telephone was also taken into the working chamber, by which instant communication could be had with the engine room in case any sudden increase of air pressure should be desired.

On February 25, 1893, operations were commenced, in the heading, under 35 pounds of air pressure. The previous work here had greatly increased the difficulties, and it was not long before the air pressure had to be raised to 42 pounds to control the water.

The excavation was advanced under a cylindrical steel roof, built up of plates 3 feet long and 1 foot wide, of $\frac{3}{8}$″ sheet steel, to the four sides of which were riveted angle bars $2\frac{1}{2}$″ x $2\frac{1}{2}$″ x $\frac{1}{4}$″. These plates were bolted together in a heading about 6 feet high. In the erection of this roof, poling boards were used for each plate, and a bulkhead carried down with each ring as erected. When the heading had been advanced about 20 feet from the rock, a 12″ x 12″ yellow pine mudsill

was introduced along the bottom of the heading, and on this the roof was carried by means of radial timber bracing. The excavation was now carried down on both sides of this mudsill, to a distance of about 10 feet from the rock, the steel roof being extended well down on the sides. A circular section was thus excavated, in which brickwork was laid, four courses thick, and with an internal diameter of 10 feet. Between March 4th and 16th a great deal of trouble was experienced. Air pressure was several times to 48 pounds, and the work progressed very slowly on account of the many inrushes of water, and softened material. It was not until the 8th of April that the last section of brickwork in the soft material was completed, and rock again entered, after passing through 29 feet of this decomposed material. Of the material met in driving through this vein, at first 9 feet of the gray decomposed feldspar was penetrated, a vein of 4 inches of hard quartz was then met, and this was followed by 6 feet of pure white decomposed feldspar, smooth and soft as plaster. The remaining 14 feet was made up of layers of feldspar and chlorite. This chlorite, deep green in color, flaky, and grease-like to the touch when wet, proved to be very troublesome material, as it was easily converted into a fluid state by the water, which was again encountered next to the rock.

At the Long Island shaft, the work up to this time had progressed to about 250 feet from the shaft. The material so far encountered on this side was a hard, seamy gneiss, bearing considerable quantities of salty water, containing iron, lime and magnesia. Soft ground was now met at this end, in a seam about 4 feet wide, of chlorite.

As this material was perfectly dry and not thoroughly disintegrated, the tunnel was timbered through this seam without difficulty. Several similar veins were thus met and passed through, until at a point 285 feet from the shaft, where after drilling for about two feet through rock, a soft green, almost liquid chlorite vein was struck, which began flowing in through the drill holes with great force.

These holes were plugged, but as it was necessary to know what was ahead, and as with 100 feet of cover between the tunnel roof and the river bottom it was thought that the condition of affairs could not be very serious, it was decided to continue driving ahead without air-pressure, and with a timbered heading. To see what the material would do, several hand-holes were put into the rock-face with the object of blasting out a hole about 2 feet square through the remaining 2 feet of rock, to the chlorite. Before blasting, however, the precaution was taken to build a bulkhead, some 40 feet back from the face. On firing the holes, an inrush of many yards of material took place, which was finally checked by some rock fragments closing the opening through the rock.

After several desperate attempts on the part of the contractors to control this material and make progress, the work was finally abandoned in the latter part of March, and as a 4-inch stream of water was now flowing from the heading, pumping was discontinued, and the shaft and tunnel allowed to flood.

At the New York end, work was still being carried on, in compressed air. The rock encountered at the other side of the soft seam closely resembled the decomposed material which had been penetrated before, and consisted of alternate layers of feldspar and chlorite with an occasional vein of quartz. It was quite soft, though requiring drilling and blasting, and eventually it had to be lined After the heading had been driven about 69 feet into this rock the company decided, in spite of the uncertainty as to the material ahead, to remove the air pressure, and to call upon the contractors to resume their contract. Upon removing the air-pressure, however, the brickwork through the soft seam proved so unsatisfactory in excluding the water, that air-pressure was again put on, and it was decided to line the brickwork with a circular cast-iron lining. Although this brickwork was only 10 feet in inside diameter, a lining was designed 10 feet 2 inches in the clear, as it was now desired to make the tunnel bore as large as possible. To put in this lining, some of the brickwork had to be cut out, which was then removed in sections, enough for one ring of plates at a time. The lining consisted of rings of plates or segments, each segment being about 3 feet long and 1 foot 4 inches wide, with internal flanges 4 inches deep, from the back of the plate. The metal in both the back of the plate and the flanges was 1¼ inches thick. All the joint-faces of the segments were planed and 1-inch bolts used for fastening them together. A complete tunnel ring was composed of nine segments and a small inverted key, about 8 inches wide. Difficulties between the company and the contractors, which had been brewing for some time, now culminated and the courts were appealed to to settle their differences. This caused a cessation of work for a short time until the company were empowered to take possession and resume the work of construction for themselves. The work of putting the cast-iron lining into the brickwork was necessarily a very slow operation. The lining was extended well into the rock on both sides of the soft vein, and a wall built at both ends between the rock and the iron lining, to confine the Portland cement grout which was now introduced back of the plates. To effect this grouting 1¼-inch holes had been drilled and tapped through the back of several plates in each ring. Through these holes the grout was pumped by means of a Cameron pump, and after the space between the brickwork and the lining had been thoroughly grouted, the work was found, on taking off the air pressure from the heading, to be perfectly water-tight. It was

not until toward the end of July that the work of lining the brickwork was completed and driving ahead in the rock was resumed. Then, when an advance of only 10 feet had been made, a second soft seam was encountered about 80 feet beyond the first one, and a test pipe was driven to a horizontal depth of 70 feet without encountering anything solid. To avoid further delay the driving of the test pipe was discontinued at this depth and preparations made for advancing the heading. For this test pipe 1½-inch common wrought-iron pipe was used, which was driven in by a small machine-drill and washed out at each lengthening of the pipe with a ¼-inch wash pipe. From these washings the different materials penetrated were sampled, with the following tabulated results:

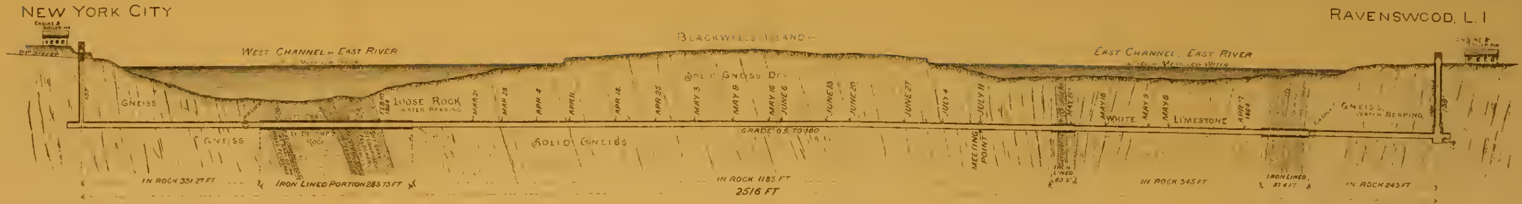
3 feet gray decomposed feldspar and chlorite.
11 feet soft black mud, containing lumps of carbonized wood like charcoal.
19 feet hard black mud and sand, with nodules of pyrites.
22 feet gray decomposed feldspar.
4 feet decomposed feldspar and chlorite.
11 feet gray decomposed feldspar.

Water was again found next to the rock, but was considerably held in check by the compressed air. As from the results of the test pipe there were no special difficulties to apprehend from the indicated material, it was decided to drive ahead, under the open heading method, as this involved no delays in waiting for special machinery. The light steel cylindrical roof was again used in advancing the excavation, but for the permanent lining the cast-iron rings were to be introduced instead of brickwork, as heretofore. A start was made on the 7th of August to drive the heading into the soft material, but two days later, after the work had been advanced six feet into the soft vein, orders were received to suspend all work on account of the great financial depression of the time. This was unfortunate, and could it have been anticipated a few days the heading into the soft material would have been left unopened. As it was now, from being first disturbed and then abandoned, the water was allowed to soften up the black mud in the heading, and, in spite of the bulkhead, a considerable quantity of the material was washed into the tunnel. This stay of proceedings was utilized by making horizontal test boring in the heading on the Long Island side. At this shaft, no work had been done since the departure of the contractors beyond the building of a brick bulkhead and air-lock in the tunnel. Compressed air had then been put on, which considerably reduced the amount of water flowing into the tunnel from the heading. The action of the compressed air had been somewhat peculiar, for notwithstanding the great depth of the tunnel below the river bed, at 10 pounds pressure the air began to

escape through the heading, and with a pressure of 35 pounds per square inch small bubbles of escaping air could be seen rising to the surface for over 300 feet, up and down the river. This seemed to indicate that the ground above the tunnel had been honey-combed up to the river bottom by the previous washing-in of such quantities of the soft green chlorite. As it was known that there were detached lumps of rock in this soft vein, 2-inch heavy pipe was used for the test boring, with drive-well couplings, and a circular, hollow steel bit for the cutting end. This pipe was driven in the same way as the one on the New York side, and after passing through chlorite and various kinds of soft rock fragments, solid rock was again met at 32 feet. Into this rock a hole was drilled to a depth of 54 feet, using a small bit on the end of a 1-inch pipe and drilling through the test-pipe. The rock beyond the soft seam was a soft white limestone.

With the prospect of resuming work the question now arose as to the best method of proceeding; and, as a great deal depended upon the success of driving through the present headings, it was strongly recommended that the safest and surest method, that of shield-tunneling, be adopted in both headings, although necessarily entailing a large expenditure in plant, and delay in time for installation. This plan met with the company's approval, and a shield and hydraulic plant were designed. As the nature of the material to be penetrated beyond the test-pipes was unknown, this shield was so made that in passing from rock to soft material, or back again to rock, it could be erected or taken apart again with a minimum of time and labor, so that it might almost be called a *portable* shield. As in both the tunnel-headings there was but one air-lock, and as it was inadvisable to remove the air-pressure from the headings, the different parts of the shield had to be of such size as could be passed through the air-lock doors. This was accomplished by dividing the shield transversely, separating the tail-end section, or that which overlaps the tunnel, from the cutting-edge section containing the working chambers. These two sections were, of course, circular, 11 feet $\frac{3}{4}$ inches outside diameter. The tail-end section was 3 feet 6 inches long, and the cutting-edge section 3 feet 8 inches long. Both of these sections were again divided, longitudinally, into four quadrants. The outside shell, in both tail-end and cutting-edge sections, was made up of one $\frac{1}{2}$-inch and one $\frac{3}{8}$-inch steel plates riveted together, and, at the four quadrant joints, there were $\frac{1}{2}$-inch butt-straps 12 inches wide running the whole length of the shield and uniting the quadrants and the two sections. The middle diaphragm, separating the cutting-edge and tail-end sections, was made of two plates, one riveted to each of the two sections, and these two plates bolted together with the butt-straps united the sections.

The cutting-edge section contained two platforms, one vertical and one horizontal, of the same length as the section.



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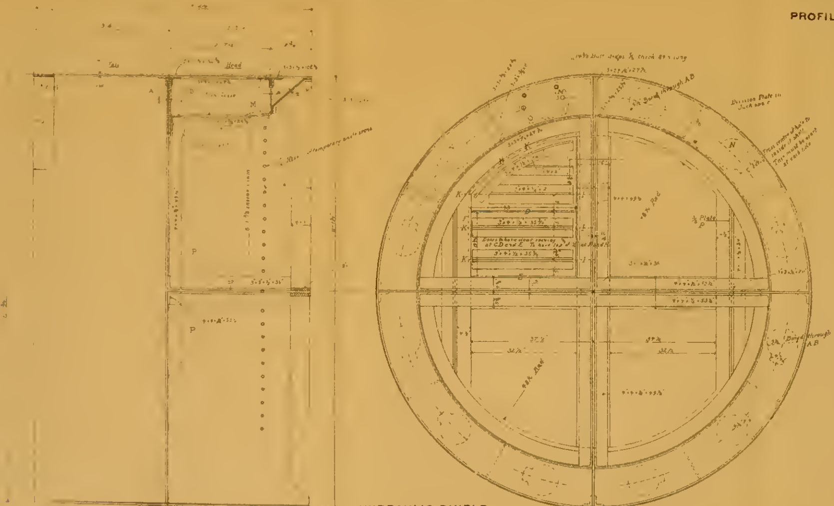
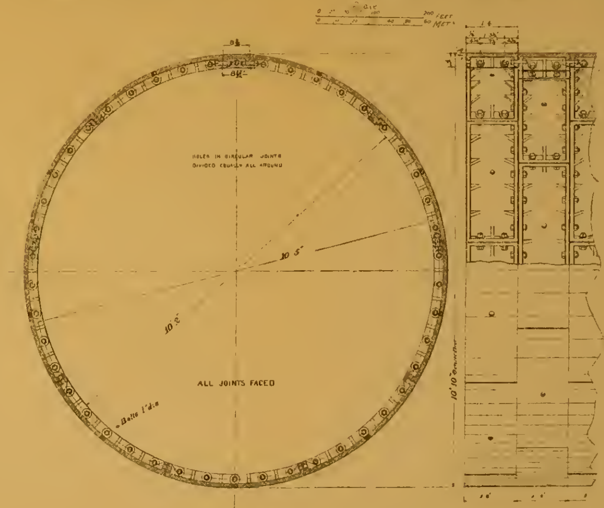


HYDRAULIC SHIELD.



CAST IRON SEGMENTAL PLATES FOR LINING.

To erect this shield the only riveting necessary was at the four butt-strap joints in the tail-end section, where it was necessary to preserve a flush surface on both sides of the outer shell. In the cutting-edge part countersunk bolts were used through the butt-straps. About 380 $\frac{7}{8}$-inch bolts and 160 rivets were used to erect the shield. Two doors closing each of the four working chambers were hung on the vertical platform, and were provided with fastenings so that the whole face could be easily closed.

To drive the shield 12 5-inch hydraulic jacks were used, designed for a working pressure of 5,000 pounds per square inch, or 600 tons on the whole shield. These jacks were controlled by two block-valves, one placed on each side of the shield. Each of these block-valves consisted of six independent valves all in one compact casting, each of which had a pressure and exhaust stem. Half-inch XX pipe was used for connecting each jack with its valve, and 1-inch hydraulic pipe was used for the pressure-main which was connected with the shield block-valves by three swivel-joint connections. To furnish the pressure, a very compact little pump, designed by Watson & Stillman, of New York, was used without an accumulator, the pressure being very nicely governed by a steam-regulating valve.

On September 22d work was resumed on the New York side, with a small force of men working days only, to excavate in the rock an enlarged chamber about 15 feet back from the face, in which to erect the shield. This chamber was made circular about 15 feet in diameter and 10 feet long. Back from this, the rock was taken out in a circular form of about 11 feet diameter, for some 14 feet, or enough for about 10 rings of the cast-iron segments which were here erected in the rock, the spaces between being thoroughly grouted with Portland cement. These rings were thus made solid in the rock to withstand the thrust of the shield-jacks upon the lining. The blasting necessary in this work was made as light as possible, but it was not without its effect upon the soft material in the heading, a considerable quantity of the black mud being washed through the bulkhead, while the braces showed signs of a heavy strain from the squeezing of the material. The shield arrived at the works on November 10th, and the work of erection was immediately begun. The sections were lowered down the shaft and taken through the air-lock to the shield-chamber. On the 17th of November the shield was all assembled, and riveting the tail-end sections was commenced. For heating the rivets in the air-chamber a forge was used, with a hood to which was connected at the top, a two-inch pipe with a valve which extended through the air-lock bulkhead. By means of this pipe all the obnoxious gases from the furnace were removed from the air-chamber. After the riveting was finished, the shield was brought to its right position for line

and grade, the hydraulic jacks and valves put in place, and the necessary connections made. On the 24th of November word was received that the work on the New York side was to be pushed with all possible speed, and a force was at once organized of three gangs, working in eight-hour shifts. More rings were built on the ten rings already anchored in the rock, until the tunnel-lining was brought within the tail-end of the shield.

The shield was now advanced until it was necessary to disturb the bulkhead, the remaining bench ahead of the shield being blasted out as the shield progressed. The most difficult part of the work was now reached, for at the point where the shield entered the soft, black mud on top there still remained about 12 feet of hard rock in the bottom, as the dip of this vein was over 40° toward Long Island. Blasting had therefore to be continued in the bottom pockets of the shield after the top had entered the much softened material. As soon as the bulkhead was passed it was with great difficulty that the bottom pockets could be kept clear of the black slush from overhead. The material had become so softened along the rock face that it was almost impossible to confine it, and several rushes of inflowing material occurred, until finally an open connection with the river was established, and the tunnel was visited by crabs and mussels, together with boulders old boots and shoes, brick, and tinware direct from the river bottom. Notwithstanding these adverse circumstances the work was still progressing, although in 45 pounds of compressed air, which was now escaping through the heading and causing a very violent ebullition on the river surface. This upward current of air held in check the downward current of water, so that no efforts were made to prevent its escape. On December 13th the shield finally cleared the rock and was now fully entered into the soft, black mud. The main difficulty now surmounted, the work progressed more rapidly, and the shield soon reached undisturbed material, which was found quite dry and hard. It was still the same black mud, with occasional lumps like charcoal, and numerous nodules of pyrites, which glistened like silver in the black peat-like mud. Mattocks were used by the men in the working chambers, who would clean out these four compartments to within a foot of the cutting edge. As soon as this was done hydraulic pressure was put upon the jacks, sometimes to the amount of 5,000 pounds per square inch, and the shield forced ahead 16 or 18 inches, enough for another ring of plates, the working chambers again being filled with the displaced material. On the 24th of December the last of the black mud was passed through, and lying next to it, at an angle of 40° towards Long Island, white decomposed feldspar was found, containing fragments of decomposed quartz charged with sulphuretted hydrogen. An important departure was now made in the method of

erecting the cast-iron lining rings by breaking joints with the segments. In all the iron-lined tunnels it has been the established custom to erect the rings with continuous horizontal joints. For some reason it was thought inadvisable to attempt breaking joints with the segments. The writer's experience in the Hudson tunnel had shown him the importance of obtaining, in soft, squeezing ground, a perfectly rigid tunnel-ring. In a material exerting hydrostatic pressure the tunnel lining is subjected to a resultant strain, tending to flatten the ring, or decrease its vertical diameter. Any yielding to this strain results both in increasing the deforming pressure and in decreasing the power of the ring to resist the strain. In a lining erected with continuous joints the rigidity of the ring is dependent upon the bolting in the horizontal joints. At the Hudson River tunnel a ring of plates were bolted together lying flat on the ground, the plates all brought to a true circle, and the two $1\frac{1}{4}$-inch bolts in each joint well tightened. Upon raising this ring with a derrick, so that it stood erect, the ring was flattened three inches by its own weight. At the gas tunnel a similar experiment was made; two rings of plates were bolted together, breaking joints, one ring being revolved two holes. These two rings were then raised upright, but no flattening could be detected. By means of a turnbuckle a measured strain was now brought upon the rings along the vertical diameter. At 16,000 pounds the vertical diameter was shortened $\frac{1}{2}$ inch, the flanges of the plates cracking where the turnbuckle was attached. In these two instances there was, of course, a great difference in the size of the rings, those in the Hudson tunnel being 18 feet inside diameter, while those in the gas tunnel were only 10 feet 2 inches inside diameter. Aside from the rigidity gained, breaking joints has proved much the better plan in other ways. With continuous joints, two things are apt to occur:

First.—The joint-face where two rings meet may become slightly warped; that is, all points on this face of the ring will no longer lie in the same plane. This may be caused by carelessness in allowing dirt to get into the joints between the rings. When this once occurs the warping increases with every additional ring till true joints can no longer be made.

Second.—The rings may be erected so as to depart gradually from a true circular form. This latter case is impossible where the joints are broken, and, in the former instance, by breaking joints, the error is divided and distributed around the ring until it disappears. On January 16, 1894, the end of the soft seam was reached with the shield, and rock was again entered after having passed through 98 feet of soft ground. This rock resembled slightly the rock on Blackwell's Island. It was in a much shattered condition, with many loose heads and small, soft veins. As this material required support in the heading and a permanent

lining, and as, in its present condition, there was no assurance that it might not again pass into soft material—shield tunneling was still continued. Small machine-drills were set up in the four working chambers of the shield upon arms bolted to the vertical platform, and the rock, drilled and blasted, just ahead of the shield. The progress of 4 feet per day was made in this material, of which there was about 65 feet, the rock then becoming much more solid with a roof that was self-sustaining, arrangements were made for removing the shield. On February 18th the work of removing the shield was begun, and two days later everything was ready for the regular rock-tunnel work in the heading, the shield having been taken apart and removed in that time. At about the time that shield-tunneling was being discontinued at New York it was being installed at Long Island. An entire duplicate plant had been ordered for this side, for although it had been originally intended to use one shield for both headings, it was later deemed advisable to provide a shield for each heading, so that there might be no delay, should soft ground be met, in both headings at the same time. In passing through the soft seam at Ravenswood with the shield, no especial difficulties were met. The material proved to be a mass of soft rock fragments, boulders and cinder-like stones imbedded in soft, green chlorite. About a month was consumed in passing through this seam, removing the shield, and prolonging the cast-iron lining well into the rock on both sides of the vein. With both tunnel headings now in rock, remarkably rapid progress was made, and as progress now had become of great importance to the company, a liberal bonus, arranged on a sliding scale, was given the foremen for work done over stated amounts. Up to the time of the headings meeting an average progress of 69 feet per week was made, while in rock, on both the New York and the Long Island sides. The *record week* of the work, was the one ending June 27th, when at Ravenswood 95 feet was driven, while on the New York side, the heading was advanced 101 feet, making a total for the week of 196 feet of tunnel driven. Soon after the rock tunneling had been resumed on the New York side, this heading reached Blackwell's Island, and the troubles on this side were over. But at Ravenswood with the heading in white limestone there was every reason to expect further soft seams where the rock should change to the granitic gneiss of Blackwell's Island. These expectations were not disappointed, for after passing through 350 feet of the limestone, and when within 200 feet of Blackwell's Island, a soft seam was met, and air-pressure had to be once more used in the heading. As this seam was but 14 feet in width, and presented no especial difficulties, the tunnel was carried through it without using the shield, the cast-iron segments being erected under a timber roof. Gneiss was encountered on the other side of this soft vein,

which brought with it the assurance that the last of the soft ground had been passed. On May 16th a serious loss and delay was caused by a fire which destroyed the New York works. The fire started in an adjoining picnic ground, containing many light frame structures, which caused so fierce a conflagration that it was impossible to save our works. This caused a delay of three weeks in the time of the tunnel's completion. On July 11, 1894, the remaining 15 feet of rock between the headings was blasted away, thus opening the pioneer tunnel under the East River, two years from the time when ground was first broken. Some weeks were spent in clearing up and shutting out the water in the wet places. A three-foot gas main was now laid through to New York, and on October 15th gas was delivered into the city, accomplishing the purpose of the tunnel.

THE ABOLITION OF GRADE CROSSINGS BETWEEN RAILROADS AND HIGHWAYS.

PAPERS READ AND DISCUSSIONS HAD AT THE MEETINGS OF THE BOSTON SOCIETY OF CIVIL ENGINEERS, SEPTEMBER 21, 1892, AND DECEMBER 19, 1894.*

I. The Gradual Abolition of Highway Grade Crossings.

BY THE LATE AUGUSTUS W. LOCKE.

[Read September 21, 1892.†]

IN the United States, the grade crossing is now the rule, while the crossing above or below grade may properly be called the exception. And in this respect there is but little difference between city and country. In a few cities, as, for instance, in New York, Philadelphia, Baltimore and Rochester, a good deal of work has been done by way of remedy; and in Hartford, Springfield and Boston a considerable expense has been incurred, mostly applied to a few crossings, and a good beginning has been made. But, as a general thing, throughout the land the city streets cross at grade.

Literature relating to this subject seems to be scarce. It has not engaged the attention either of engineers or of the public until within a very few years. I do not know that anything was written before the year 1884. At the present time there are five American engineering reports, with the comments thereon in the engineering papers, and there are articles in the reports of the Railroad Commissioners of Massachusetts, Connecticut and New York, printed from time to time. It does not appear that English engineers have written much on the subject, or, if they have, it has not become very widely known, as I have inquired

* Manuscript received April 22, 1895.—*Secretary, Ass'n of Eng. Socs.*

† Owing to the fact that the author of this paper had entered into a contract with the publishers of a magazine to prepare one or more articles upon the subject of grade crossings, and that it was a stipulation of that contract that the information should not be used for *publication* until after the appearance of the magazine article, it has been found necessary to withhold the present paper from publication in the proceedings of the Society. The delay in the appearance of the magazine article has been occasioned, in part, by the author's death, which occurred before the articles were entirely completed.

As the publication of these articles will not occur before September, it has been thought best to print the following brief abstract from the paper in connection with the other matter now presented.—*Secretary, Boston Society of Civil Engineers.*

of a considerable number of them, including the Secretary of the Institution of Civil Engineers, of London, and have been unable to find anything.

That literature of the kind is not very plenty is shown by the fact that the descriptive Index of current engineering literature published by the Association of Engineering Societies, and covering the years from 1884 to 1891 inclusive, contains, so far as I can find, only one allusion to the subject under any head, that one allusion being to the German Report translated by Professor Swain in 1889.

In the report of the Railroad Commissioners of Massachusetts for 1884, there is a chapter on the subject, given in response to a request from the Legislature. In this chapter the subject is discussed, but no remedy is suggested. In 1887 and 1888 reports on the grade crossings in a part of the city of Buffalo were made by the Railroad Commissioners of New York and also by a Board of Engineers consisting of John Bogart, Arthur M. Wellington, George E. Mann, George W. McNulty, Walter Katté, C. W. Buchholz and Henry Flad. These reports contained recommendations as to what changes should be made, and estimates of the amount of change.

On February 1, 1889, a report was made to the Legislature of Massachusetts by a Board of three engineers, members of this Society, George A. Kimball, William O. Webber and the writer. This report set forth plans and approximate estimates for the relief of eight cities and fourteen towns, and recommended against the establishment of new grade crossings. The Board recommended that the work of abolishing existing ones should be begun on a systematic plan, and that some Board or Court should be clothed with authority to carry it out, and held that a period of forty years would be a reasonable time to allow for getting all the work done.

In the report of the Railroad Commissioners of Massachusetts for 1889, the subject was discussed at length. In this report the Commissioners discussed the means by which the danger at grade crossings may be diminished by reducing the speed of trains at unprotected crossings on branch lines, by changing the location of the highways so as to cross at right angles, by removing trees, rocks, bushes or banks which obstruct the view, by the use of electric signals and by the use of gates and flagmen, and by the arrest and punishment of any who risk their lives by crossing when gates are shut or flags displayed. The Commissioners did not approve of prohibiting new grade crossings altogether, nor did they express any opinion as to what means could be adopted for bringing about a separation of grades at existing crossings.

In their report for 1890 the Railroad Commissioners reported again on the subject, repeating their recommendations of the previous year.

The Board also strongly urged, in a general way, that the grade crossings ought to be abolished, but did not go into the subject sufficiently in detail to suggest methods of procedure.

In their annual reports the Railroad Commissioners of Connecticut and of New York have furnished information on the subject, and have discussed it from time to time.

On February 1, 1892, a report was made to the city of Worcester by a Board of Engineers consisting of three members of this Society, Mr. Charles A. Allen, Mr. John W. Ellis and the writer. This report has been printed. In it are set forth methods for abolishing all grade crossings within the city limits.

Several methods are discussed for the thickly settled part of the city, and their merits and demerits are explained, but the plan there recommended is to raise the tracks and depress the streets. For crossings in the suburbs, such plans are recommended as seemed best adapted to each locality. In this report the amount of travel on the streets and on the railroads is shown, and the interests of the people who travel on the streets and on the railroads, together with those of the railroad stockholders, are discussed. It was found that, at several crossings, the travelers along the street outnumbered the travelers along the railroad, at one point three-fold. The authors of this report recommended brick or stone arches for carrying the tracks across the street, and where, owing to lack of head-room or long span, arches were found undesirable, they recommended iron bridges with tight floors. On page 75 of this report the following statements are made with reference to bridge floors:

"The ordinary railroad bridge floor is a very unsatisfactory thing to have over a city street. The noise of trains, when passing at fast speed across such a bridge, is very annoying and frequently frightens horses. Grease from the cars and engines and from the track falls upon the street beneath. The ties and rails are apt to become very dirty in the vicinity of stations and yards where trains are accustomed to stop and where switching is done. When it rains, or when snow or ice thaws, the water, which drips from the bridge upon the street below, is apt to be dirty. Those walking upon the sidewalk can be partly protected, as is often done, by a wooden roof extending to the curbstone, which is necessarily a somewhat uncouth and disagreeable structure, but it is impracticable to protect the people passing in the drive-way when this kind of a floor is used. The water which runs down between the tracks, along the railroad embankment, is very apt to be neglected and allowed to run down over the face of the abutment to the sidewalk and make a very disagreeable state of things. And in the winter the drippings generally freeze upon the face of the abutment and upon the

sidewalk. All of these annoyances can be avoided by the construction of brick or stone arches to carry the tracks over the city streets wherever the span and amount of available height will admit of it. At all other places iron bridges with solid water-tight concreted floors should be constructed."

The latest printed report on the subject was made to the city of Buffalo on the 9th of the present month, and was prepared by Mr. E. L. Corthell, of Chicago, and the writer. This report makes recommendations for abolishing 76 crossings, mostly by lowering the streets and raising the tracks. It deals with the peculiar state of things existing in Buffalo, where there are 500 miles of main tracks and yards within the city limits, and a very large number of crossings, said to be 300. The report deals only with the principal business part of the city. It has been recently published in the Buffalo papers.

In the Buffalo report the position is taken that the streets should be maintained at their full width, and the railroads provided with means of passing at full speed to and from their stations ; that but few streets should be closed and that the present ruling grades for streets in the various sections of the city should not be increased. Three per cent, was recommended as a maximum, that being the heaviest now existing in the vicinity. Nearly the whole of the area under consideration is less than 18 feet in elevation above the ordinary level of Lake Erie. The report recommends a head-room of 20 feet over tracks, and from 12½ to 15 feet over streets. In 18 months, 61 travelers, on these streets, were killed while attempting to cross the tracks.

The first work done in the city will often determine the system upon which subsequent work must be carried out. For instance, if one important street is carried under the railroad without changing the tracks, the tendency is to carry the other streets in the vicinity under in the same way, because (1) in such a case the tracks cannot be lowered much without throwing away the work already done, (2) it would not be well to lower one street and raise another in its immediate vicinity, and (3) it would probably be said that if one street has been depressed to a certain grade the others could also be depressed to the same grade. It will generally be found most advantageous, to the railroad and to the cities, to have a full plan decided upon before going to work, in order that all interests may be considered together—the station, the bulk tracks and the private sidings, as well as the streets.

Where sidings are not too numerous it will sometimes be found to be cheapest to raise or lower the tracks, rather than to confine the change altogether to the streets. In cities, the latter plan is apt to entail large expenses for damage done to adjoining estates, while, as a general thing, damages for changes in the grade of the railroad cannot

be recovered by adjoining owners. A wise provision in our laws calls for a clearance of 18 feet above the rails, and, if any change were to be made from this figure, it would probably be increased, as the tendency is to increase the heights of all cars. Measurements recently made in the city of Buffalo showed that there were running into the city, freight cars measuring 14.2 feet from the rail to the top of the running-board, and others 14.8 feet to the top of the brake wheel, while on the Michigan Central Railroad cars were allowed to be loaded to a height of 15 feet 4 inches. Continuous air brakes on all freight trains, much as they are to be desired, do not seem to be within our reach at present, and it may be doubtful whether it will not for many years be necessary for men to be on the tops of freight cars and to use hand brakes in and about freight cars and stations. So I am unable to see any practicable way to avoid raising the streets, where it becomes necessary to raise them, to the full height required by the present law of this State, or, it may be, even higher, as is now required on various railroads in the West. And, of course, every extra foot of height in such cases adds very largely to the expense of the work and to the damage.

While the necessity of the abolition of the crossings will probably not be seriously questioned here, it will, on the other hand, be granted that the expense would be very great, and the question naturally arises whether the community can afford it. The public at large will finally have all the bills to pay. The expense may be brought upon the railroads somewhat uniformly, so that no one road shall be given a great advantage over the others, but if it should increase the cost of transportation by increasing the fixed charges, or if it should prevent the rates from being lowered as they have heretofore been lowered from year to year, whatever burden should arise, it would have to be borne by the people at large, for whom the railroads do business. The English have been able to afford these improvements from the very beginning of their railroad system; we are richer to-day, and our wealth per individual is greater. In communities like the State of Massachusetts, the inhabitants have advanced in wealth far beyond the necessity of confining themselves continuously to getting food and protection from the weather. They are in condition to have many things which a settler in a new country would not expect. We seem to afford elegant stations, and cars which cost a small fortune apiece, and probably we shall afford to have the crossings abolished gradually as the opportunity presents itself.

The passenger stations also demand some attention in considering this question. Some of our passenger stations are among our very worst and most dangerous grade crossings. On some of our double track roads there is no restraint whatever. Persons pass back and forth across the

tracks at will, boys play on the tracks in front of fast express trains passengers have to cross the tracks to reach their trains. Important stations are often placed at a highway grade crossing, and the greatest care, on the part of the gate-keeper and the enginemen, will not prevent accidents. The English stations are far superior to most of ours in this respect. Their express trains run at full speed through stations where a large business is done; and there is seldom any reduction of speed except where the train is due to stop. The ability to do this in safety is obtained only by keeping the people out of the way. Bridges, or subways, are used for passing from one side of the station to the other, and the passenger, when entering a station where through trains pass, shows his ticket and goes to the proper stairway, which takes him to the platform from which his train will start. We have a very few stations arranged somewhat after this manner.

I know it is sometimes said that our gates are good enough, that they indicate to the people that trains are approaching, and that it is the duty of all to take warning; that level passenger stations, with no way of access to half the trains except by crossing tracks in front of the other half, or by going through them, are all right if people will only exercise care. But I would like to be understood as disagreeing entirely with that theory. The time and energy of the people ought to be directed to other matters than watching for their lives when traveling on the highway, or when taking trains at stations, especially so when well-known remedies are within reach.

And it should further be borne in mind that there is one portion of our population, the children, who are not supposed to be able to exercise the constant vigilance and care of which older persons are capable. They have to pass along the highway, to school and elsewhere, alone. Who is to look after them?

II. Abolition of Grade Crossings.

By James W. Rollins, Jr., Member of the Boston Society of Civil Engineers.

[Read December 19, 1894.]

In the early days of railroading in this State, from 1830 to 1850, when railroads were new, money scarce, and the public eager to get better facilities for commerce and travel, the main question at issue was, *how* to get the railroads built, and not in what manner and under what restrictions shall they be built.

Two or three trains a day sufficed to accommodate both freight and passengers, and the crossing of the highways, not so numerous then as

now, must have afforded the natives a good and welcome chance of seeing the engine and cars as they went by.

Grade crossings then must have been popular, for the cheapness of their construction saved the railroad companies much money, while their use saved the public much labor, both of man and beast, in climbing up and down in order to pass over or under bridges.

So the grade crossings came, thousands of them, and not until the last twenty years has public opinion been turned against them.

In justification of the early methods of railroad construction in which grade crossings were considered to be not an evil, but often a necessity, the Railroad Commission has several times expressed its opinion. In 1889, it said:

"It is unnecessary to go into a careful examination of the law in regard to the establishment of grade crossings at different periods in the history of our railroads. For the purpose of the present inquiry it may be presumed that the existing grade crossings have been created under the authority of the Legislature, and subject to such limitations as it has from time to time seen fit to impose.

"When the main lines of the railroads were built in this State, the problem was a somewhat different one from that which presented itself in England and on the Continent.

"There the districts through which the railroads were to run were comparatively thickly settled. There was greater immediate necessity for avoiding grade crossings, and the prospective earnings of the roads were such as to justify a larger expenditure than could have been profitably incurred in a district such as the interior of our State was from forty to sixty years ago. After the feasibility of the transportation of passengers and freight by railroad was demonstrated, the next question was, whether it would pay, and, in determining this question, the original cost of construction was a most important item. It is probable that the building of our roads, and the consequent growth and prosperity of our State, would have been retarded many years if the Legislature, in the infancy of railroads, forseeing the difficulties which now beset us, had legislated for the benefit of this generation rather than for their own.

"In considering the evils attendant upon grade crossings, and the means of avoiding them, it must, therefore, be borne in mind that the existence of grade crossings is not due, as a rule, to any blindness on the part of the railroad corporations, much less to any intentional fault of theirs, but rather to circumstances which they could not control, and which are appreciated by the public; so that the existing grade crossings not only were created by the authority of, and with the sanction of, the Legislature, but, generally, were also created in accordance with the wishes of the vicinage.

"The history of the creation of grade crossings fifty years ago has its counterpart to-day when the building of a new road is proposed. The profitableness of the road is generally questionable. It is projected to furnish facilities to a promising district, in the hope that it will develop the district. Frequently the stock of the company is subscribed for by the people along the proposed route ; and these people, being anxious that the actual cost of their road should be as low as possible, are the very ones who pray for grade crossings—urging, with facts to back them, that the road cannot be built if grade crossings are not permitted.

"Even those people, living along the line, who are not subscribers to the stock, in their gratification at the prospect of railroad facilities, heartily second any efforts on the part of the corporation to secure permission for crossings at grade."

The report of 1880 contained this expression in regard to grade crossings : "All men conversant with railroads deprecate the increase, and even the existence of these nuisances ; and, in general, the community agrees with them, but, in each special application, a different feeling is shown. Then the expense of an overhead crossing by the highway, with the unsightliness of the structure and the wear of horse-flesh, or the inconvenience of a depressed way with its injury to adjoining property, is urged against all considerations of safety. Each citizen is confident that no accident will happen to him, or to his family ; while many residents in the locality interested, fear some immediate injury from any other mode of crossing than at grade."

The public seems now to take this position : that when the railroads were built, they should have avoided these grade crossings and built bridges, and, as they chose to do differently then, they must now correct their errors and spend millions thereby.

In fact, it sometimes seems as if public opinion opposed these crossings, merely because corporations made them, and not on account of any warrantable objection to them, based on facts.

No one denies that grade crossings are dangerous—particularly to those who do not look out for their own lives.

From 1879 to 1889, the average number of persons killed and injured on the 2,000 odd crossings in the State was 43, of whom 22 were hurt at protected crossings, and therefore, presumably, on account of their own carelessness.

In 1893, on 2,216 crossings, 993 of which were protected, 76 persons were killed and injured ; 36 at protected, and 40 at unprotected crossings.

The consistency of our Legislature and of the public does not appear to advantage in their treatment of the general question of grade crossings.

The former pass laws, involving the State in an expenditure of $5,000,000, to abolish grade crossings, and then grant charters, indefi-

nitely, to electric car companies who pay nothing for their location, and who, in their crossings at grade with steam roads, create a danger far greater than ever before existed.

Comparing the statistics of accidents on electric roads with those at grade crossings on steam roads, we find, that in the year 1893, as stated, 76 persons were killed or injured on steam roads, while, in the year ending September 30, 1893, there were 595 persons killed or injured by electric cars on public highways.

In the electric railway construction of to-day, history, with all the faults and short-sightedness of the past staring it full in the face, is repeating itself, with the certain knowledge that before long another overturning of things, including public opinion, must come, and that the public highways must be kept clear of everything which endangers the lives of those who travel thereon, either on foot or in vehicles. At the present time the public wants electric railways, and is willing to do anything, to run any risk, to get them; and it will, in so doing, impose upon coming generations just such a burden as has been imposed upon us by these thousands of grade crossings made years ago.

But the crusade has begun—grade crossings are going, electric and other wires are being buried, and the beginning of a return by the public to common sense and consistency in the matter of electric cars has been made, and one step toward the desired end, the prohibition of a grade crossing of an electric railroad with a steam road, is being urged by the public and the press, and to such an extent that it is to be hoped our coming Legislature will pass laws, regarding electric roads, in accordance with those already existing and controlling steam roads, the construction of which is surrounded with all sorts of safeguards for the public.

The selectmen of a town, or the mayor and aldermen of a city, must approve their location, and this, in turn, must be passed upon by the county and railroad commissioners, while, for an electric road, the permission of the selectmen or aldermen only is necessary, even though the proposed location creates a grade crossing with a steam road.

Legislation against grade crossings began in 1849, when a commission was appointed to consider the crossings at the northern part of the city of Boston. This applied to crossings of railroads with each other, highways then not being considered.

Prior to 1872 the law contemplated that railroads should pay the whole cost of the abolition of grade crossings, but in that year provision was made for an equitable apportionment of the expense between the railroads, on the one hand, and the cities, towns and counties on the other. This law provided, however, for action only where all parties in interest could agree, and left the apportionment to a commission of three men—one representing the town or city, one the railroad, and the third a member of the Board of Railroad Commissioners.

In 1876 the Legislature passed a law requiring the consent, in writing, of the Railroad Commission to a crossing at grade of a railroad and highway in addition to the authority of the County Commissioners.

Since then, however, many new crossings have been made, and the Commission, while generally opposing them, have, in certain special cases, approved of them and allowed their construction.

In 1881–82 numerous crossings were granted to the Massachusetts Central Railroad in Waltham and Belmont, the almost universal sentiment of the citizens of these towns being in favor of such construction.

Our legislators seem to be always ready to frame and pass laws for the general benefit of the Commonwealth, but also equally ready in special cases, where facts and conditions may seem to warrant them, to pass others which render the general laws null and void, the present only being considered. In compliance with the general laws and public opinion, the Railroad Commission has for many years been strongly opposed to grade crossings, sometimes refusing to allow them, even if such a refusal might "imperil the whole undertaking;" while again, in other cases, it offers this same reason, together with others good and sufficient, as their ground for granting such crossings.

These special laws of the Legislature are often the means and reason of such permission, the Commission taking the ground that the Legislature, having granted to a company a charter to build a road upon which it is evident that grade crossings must be created, the Commission can but give its consent, on the best conditions obtainable and under such restrictions as may be enforced.

As late as 1893 five grade crossings were granted to the Southbridge, Sturbridge and Brookfield Railroad, because, it is understood, of such provisions of their charter as made it impossible for the Railroad Commissioners to act differently.

Two different opinions of the Board are as follows.

In 1890 the Board reported:

"During the past year the Board was called upon to approve—and it did approve—of nine grade crossings for the Grafton and Upton road. The community desired that the road should be built. It would not have been built had not grade crossings been permitted. The Board did not feel justified, in consequence of the slight danger incurred at such crossings at grade, in refusing its approval, thereby depriving the community of the railroad facilities which it much desired."

In 1892, upon request of the Plymouth and Middleborough Railroad for a grade crossing in the town of Middleborough, the Board made this report:

"Upon an examination of the premises the Board refused to give its assent to a crossing of Plymouth Street at grade. This street is

crossed by a proposed line of the railroad at an acute angle, being an angle less than forty-five degrees, and the estimated expense of avoiding a grade crossing was twelve thousand dollars. This expense could, however, be diminished considerably by changing the location of Plymouth Street, so that it should be crossed by a railroad more nearly at a right angle. It was urged, with great earnestness, that the refusal of the Board to assent to a grade crossing on this street would so increase the cost of building the railroad, that the success of the enterprise would be imperilled. The conditions of the case, however, did not seem to be such as to justify granting the petitioners' prayer."

The Legislature, in 1884, passed this resolution :

Resolved, "That the Railroad Commission examine and report to the next Legislature, upon the subject of providing for the gradual abolition of grade crossings in cities and the populous parts of towns."

In accordance with this resolution the Board reported, in part, as follows :

"It is believed that $100,000,000 would be the cost of abolishing the crossings included in the resolve of 1884—amounting to 80 per cent. of the existing capital stock of our railroad companies. This work, if done in a period of 10 years, would call for an annual expenditure of $10,000,000, and for a general suspension of dividends for that period at least.

"It should not be forgotten that every one of the crossings was made under authority of law, and by direction or permission of the tribunals appointed to decide for or against such crossings. In some cases a statute of the Commonwealth specially ordered this mode of construction.

"In some other cases, the company desired to avoid the dangers of a grade crossing, but was, at the instance of the town authorities, compelled to construct its road at a level with the highway.

"The expense of a change would be far greater than the cost of original construction over or under the highways. In many cases another route would have been chosen, by which the crossings would have been avoided, but for the favorable decision."

In 1888, the Legislature passed a resolve, that the Governor should appoint a Commission of three competent and experienced engineers, to investigate and report upon the subject of the gradual abolition of grade crossings, with recommendations as to the method of apportioning the expense of such work.

This Commission made a careful examination of the whole subject, and an exhaustive report, with estimates on the cost of the abolition of all the grade crossings in the State.

The result of this was the Grade Crossing law of 1890, with which

you all are probably familiar and under which the railroad pays 65 per cent. of the cost, and the State and the town or city the balance, the latter paying not more than 10 per cent. in any case.

Assuming this estimate of the Board, of $100,000,000, to be approximately correct, the railroads, under the law of 1890, would pay, as their share of the expense, $65,000,000, provided the conditions of the act were to be continued, after the $5,000,000, which *it* fixed as the limit of the State's interest, had been spent, and until all the grade crossings were abolished.

Of the 2,165 crossings in the State, about 1,000 are protected, at an approximate cost of $500.00 each, or a total of $500,000, per year.

This amount, capitalized at 4 per cent., gives $12,500,000 as the amount which the railroad companies can spend on crossings without loss. In addition to this cost of protection should be added the amount paid by the railroad company on account of accidents at these crossings. Of this I can find no data. The money spent in excess of the above aggregate, deducted from the 65 per cent. which the railroad company pays, is absolutely sunk by the railroad company, and no returns come from it. When all the crossings in the State are considered, it looks far better for the railroad company than when some individual crossing, or some group of them, is taken; as, for instance, on the Providence Division, where twelve crossings are abolished at an expense of probably three and a half millions of dollars, or nearly $300,000 for each one. The cost of protecting these crossings is probably $20,000 a year, or $500,000 capitalized. I do not think that the payment on account of accidents on these crossings has been anything of account for many years—so that the balance of the cost to the railroad, 55 per cent. of $3,500,000, or $1,925,000, less $500,000, or $1,425,000 goes into work from which the company gets no return from additional passenger or freight receipts, and for which they pay annually, at 4 per cent., $57,000.

On the Old Colony System, there are now under way, or before commissioners, four schemes, which will cost over $6,000,000.

These schemes are Providence Division, Chickering to Mt. Hope, Dorchester Avenue and Dover Street, Boston, and at Brockton. In addition to this, Fall River, Taunton, New Bedford, Attleboro and Clinton, and I do not know how many more towns or cities, have begun, or are contemplating beginning, action for the abolition of their grade crossings, which would probably cost $5,000,000 more. That is $11,-000,000 or more is to be spent on crossings, $7,150,000 of which must be paid by the railroad company, while the entire capital stock of the Old Colony Railroad is only $14,000,000.

Do you wonder that the railroad companies go slowly in their approval of these schemes, and that they ask where the money is to

come from to pay for them? It all comes from the public, and the public still clamors for lower rates of fare or of freight, and, on the other hand, better facilities in every way, and to crown all, the expenditure of millions to abolish these grade crossings, which originally were built to the satisfaction of the public and in accordance with all the conditions then existing.

The liberal policy of our State, in putting one-third the burden of this enormous expenditure upon the city or town and the State combined —will go a long way towards making possible these improvements, which otherwise would have been delayed, with the result of a great increase in the ultimate expense.

Under the provisions of the law of 1890 the Commission decides whether the *safety* and *convenience* of the public require the separation of grades. Having decided that the separation of grades *is* necessary, the *safety* of the public is assured, and the problem in hand then, is to provide for their *convenience*.

This means, generally, to make as little additional labor as possible for the public—to avoid obliging it to go farther out of its way, either vertically or horizontally, than necessary.

This problem of adjustment of the grades of railroads and streets, especially through a city, is the most difficult part of the problem.

The question of clearance for the highways, the amount the street is to be lowered or raised, the grade necessary to accomplish these results—all these must have due consideration.

In regard to the question of clearance, I must differ from some of you who have charge of the engineering of cities.

Many years of interested observation have led me to believe that the cases of street loads which require a clearance of more than fourteen feet are extremely rare, and that no necessity exists for such extreme loads; such, for instance, as pile-drivers, empty barrels or loads of furniture, with long-legged stools tied on top of a load already high.

When it is a question of whether the whole traveling public on the railroad must climb one or two feet of additional steps, and every ton of freight, cars, engines and all must be raised that additional height, or provision made for such sky-scraping loads, it seems to me a most absurd condition, and a " balance sheet " which is not generally made by our engineers in these days of careful examinations, and actions according to the result of such examinations.

Take the Providence Division of the Old Colony Railroad, for example. From the Roxbury, Heath, Boylston, Jamaica Plains and Forest Hills stations are now carried 2,225,000 passengers annually.

Over 50,000 trains run over this piece of track every twelve months, carrying 1,500,000 tons; so that each foot of additional rise of track

means that these 2,225,000 of passengers must raise or lower themselves that additional foot—and 1,500,000 tons be raised the same distance—in order to let, possibly, 1,000 teams through the bridges, rather than delay a couple of men ten minutes to readjust their load to a reasonable height, or 167 hours of time at $1.00 an hour for men and team, amounting to $167.00 a year. Who of you, gentlemen, would travel up 2,225,000 steps of one foot, or 450 miles, for $167.00?

Multiply this even by ten and still the difference is enormous.

And again, most of our main highways are parallel to the railroads radiating from the center of the city, and the great bulk of the teaming does not cross the railroads at all. A teamster, having been caught once with a high load, will not be caught a second time, and thus all will be adjusted in a year or two.

On the other hand, from now to eternity, or until electricity or flying machines have rendered our railroads useless, this great waste of human and mechanical energy must go on.

My judgment on such questions is that the great consideration is the convenience of the *public*—not that of the *few*—and the railroad traveling public is the one whose interests are the greatest in a locality such as those mentioned. Hence the less the railroad need be raised the better.

This is generally admitted, and plans are made accordingly, but in such plans the demand of the cities for high clearance often brings an enormous burden upon the patrons of the road and upon the railroad company for increased construction, and all this for the benefit of a very few persons who could, if they would—and would, if obliged—regulate their business to conform with that condition which the greatest good for the greatest number demands.

III. Abolition of Grade Crossings in the City of Brockton.

(*a*) Preliminary Negotiations.

By F. Herbert Snow, City Engineer of Brockton.

[Read September 21, 1892.*]

The city of Brockton is a rapidly growing shoe-manufacturing town of some thirty thousand inhabitants. Its area of twenty square miles is rectangular in shape, approaching that of a square, through

* This paper was presented in the discussion of the opening paper of this series, on The Gradual Abolition of Highway Grade Crossings, by the late Mr. Augustus W. Locke.—*Secretary, Boston Society of Civil Engineers.*

the geographical and business center of which the central division of the Old Colony Railroad runs in a southerly direction. From the town of Avon on the north, to the town of West Bridgewater on the south, there are three passenger stations, named, in order, Montello, Brockton, and Campello.

The station at Montello was built some six years ago, and is of sufficient size to accommodate this part of the town for the next ten years. The facilities of the passenger stations at Brockton and Campello, however, have for a long time been totally inadequate. In the spring of 1891 the directors of the Old Colony Railroad decided to erect a new passenger station at Brockton, and also a new freight depot. Plans were gotten out for the same, and a description given to the public through the Brockton *Daily Enterprise.* The design of this station was perfectly satisfactory. The Company's plan, however, was to locate this beautiful structure on a level with the existing grade of the tracks, which would thus effectually stop any movement towards the abolition of grade crossings—of which there are five in the immediate vicinity. Because the larger part of the city is on the west side of the railroad, while all freight has to be shipped and received on the east side of the railroad, these crossings are continually in use. The railroad company has no freight yard proper, and it therefore switches its trains through the city on the main and side-tracks, thus obliging the public to cross a veritable elongated freight yard.

This has become a serious matter. Many times the apparatus of the fire department has come flying down some one of the five streets in response to an alarm from the East Side, and has been brought to a standstill to wait for a long freight train to switch back and forth.

These conditions cause much delay and injury to business. On this account, insurance rates are higher, and land values and rents lower, on one side of the railroad than on the other. These facts, and the importance of these crossings in relation to the city's future, have caused the growth of an objection to their existence at grade. This objection, which is by no means a sentimental one, has manifested its disapproval of the Company's plans, in the form of a petition to the City Council that the Board of Mayor and Aldermen apply to the Superior Court for the appointment of a Commission, under the Grade Crossing Act of 1890, to consider the necessity of the abolition of all grade crossings in the city of Brockton. After this request had been complied with, those citizens whose property abutted on the railroad and on the streets where changes might have to be made, began to speculate as to the manner in which this stupendous undertaking could be carried out with the least injury to their private interests.

That a clear understanding of the case may be had, I will state

that manufacturers have found it advantageous to locate their shops along the line of the railroad and within about one quarter of a mile of it, so that the city has by degrees stretched out over a territory unusually long for that of a manufacturing center. For three miles along the railroad, thousands of dollars have been invested in improvements and facilities for doing business with the railroad. Side-tracks are numerous, and not a few concerns are dependent upon these for their prosperity.

To make the problem one of greater concern to private interests, Montello Street, a business thoroughfare, runs parallel to, and about 130 feet from the railroad, through the entire length of the town, and upon this street, in the neighborhood of the five principal crossings, are situated brick buildings, hotels, factories, an electric light plant, gas plant and many wooden structures. To disturb the grade of this street to any extent, would involve the city in hopeless litigation. The remonstrance to such a plan would be greater than the desire for a riddance of the grade crossings.

The more abutters sought for a satisfactory solution of the problem, the more fearful they became of the results of the damages that their property might sustain. Naturally these people, in their dilemma, looked to the Mayor of the city for assistance, as did the general public, whose suspicions that the Old Colony Railroad would not look out for Brockton's welfare except in so far as was consistent with that company's ends, had been aroused by the company's plan to perpetuate the existence of the present street crossings at grade.

Finally, the city engineer was directed to prepare and present to the Board of Aldermen, for their approval, a plan for the abolition of all grade crossings in Brockton. Preliminary plans were made. Briefly, these called for the elevation of the railroad and a depression of the streets through the center of the town, and a depression of the railroad and elevation of the streets at Campello. The plan would necessitate the abandonment of the present passenger stations and freight depots at Brockton and Campello and the construction of new ones on different sites. The passenger station at Campello, however, could be kept on the present lot, provided more land was obtained.

In order to render feasible the elevation of the railroad through the center, some eighteen acres of land, intended for use as a new freight yard, would have to be elevated from six to fourteen feet. The grade of the main tracks to the yard would then be not less than one per cent. After due consideration, this plan was adopted by the Board of Aldermen.

I believe that it is folly for a community like Brockton to attempt to force upon a powerful railroad corporation the expenditure of a mil-

lion dollars or more, no matter how great the demand for the separation of the grades of the railroad and the highways. The Directors will not be forced to make a change until they are ready to take up the work, and then the improvement must be in accord with their ideas of what is practicable.

The Mayor and Aldermen had come to a firm decision that the plan adopted by them was the only plan that would not work to the permanent disadvantage and disfigurement of the city. It was very doubtful whether or not the railroad company would see it in this light, when other plans could be designed that would not call for such radical changes in its property. Either the directors must be brought to see that their interests and those of the city were identical, or nothing could be accomplished. This task was undertaken by the Mayor, Hon. Ziba C. Keith. His arguments convinced the company that it would be easier and cheaper to abolish immediately Brockton's grade crossings rather than to wait until the city became larger.

The question then arose as to how the separation of grades might be effected, and the city's plans were submitted to the president. Finally, an agreement in writing was made, accepting the city's plans and fixing the new elevation of certain highways at the railroad, and the number of feet of "head room" required.

Upon the strength of this agreement, the railroad company and the city joined hands in securing a special legislative act relating to private crossings in Brockton. This mutual understanding has brought together, officially, the chief engineer of the railroad company and the engineer of the city, under conditions calculated to secure the very best results. This is as it should be. Who knows, so well as the city engineer, what is feasible in changing grades and lines of streets, sewers, drains, gas, water and electric wire pipes, and a thousand other things none the less important because of their number?

What railroad engineer would, unassisted, hope to devise any plan which would not be bitterly opposed by the city engineer? On the other hand: What city engineer wishes, or is competent, to dictate to the railroad engineer?

It was decided that the engineers prepare, jointly, a separate plan for each crossing, that these plans should be signed by them, approved by the President of the Company and by the Mayor of the city, and presented, with the specifications, to the Commissioners.

The advantages of this method I have not time to discuss, but I think it must be at once apparent that there is no disadvantage.

I wish to explain carefully our method of dealing with the problem of damages, which I am confident will be of more than passing interest to you. Under the pleasant conditions spoken of, it has been possible to

carry out an idea advanced by Mr. George A. Kimball, who has been associated with me as consulting engineer.

Three disinterested, competent men were appointed by the Mayor to appraise the property and estimate damages to each and every estate to be affected. A book was prepared for each appraiser. It contained a description of every estate and the alterations to be made. Blank spaces were left for amounts to be carried out, also for any necessary remarks. These men were expected to view each estate and to estimate just awards, independently of each other.

Under the direction of the City Solicitor and Clerk, several blank forms of agreement, worded to suit different cases, were drawn up and copies of each were printed.

In general, they were propositions to the City of Brockton, as follows:

"Whereas, under the provisions of Chapter 428 of the Acts of 1890, the same being entitled an act to promote the abolition of Grade Crossings, it becomes necessary to enter upon, and take from me a certain parcel of land, and to make certain changes in grade in front of my estate in connection with the abolition of the grade crossings of the Old Colony Railroad Company, at ——— Street, in the City of Brockton, County of Plymouth, State of Massachusetts; and whereas, the changes in line and grade of said street and approaches thereto, as shown on a plan for the abolition of said grade crossings, dated ————, are necessary for said abolition, I, the undersigned, owner of, or having interest in, real estate adjoining said portion of way, do hereby agree that I will accept the sum of ——— dollars, in full settlement and satisfaction of any and all claims for damages I have or may have against said City or other corporation on account of such taking of my lands, or on account of such changes of grades."

With the appraisers' estimates to refer to, abutters have been approached and requested to come to an agreement in regard to damages.

Thus far we have not failed to show to abutters that it is for their interest to make propositions of settlement. We state frankly that our interest in the matter of settlement is to know definitely what the cost of the work is to be, and that the item of damage is a large one in this amount.

In closing, I wish to express my opinion that the proper authorities of cities of the Commonwealth of Massachusetts should take the initiatory steps in the abolition of grade crossings within their respective districts.

By initiatory steps I mean not simply to submit a petition to the Superior Court for the appointment of a commission. Such a commission may consist of men not civil engineers. There is no doubt that such men as would be nominated by the State, the railroad company

and the City, each of which has its representative on the Commission, would be fully competent to determine whether or not the changes called for were a public necessity. No doubt three Commissioners might be appointed who could solve all problems attending the separation of grades of a railroad and the highways of a populous community, and adjust and fix the manner and limits of such a separation to the satisfaction of all concerned.

While such a result is possible, I believe it is extremely improbable. Under the present act, the security of the public rests entirely in the decree of the Commission, which is final. If changes are made, and if they are not satisfactory in construction or otherwise, there is no possible redress. The commission ends with the decree. If the city authorities do not like what is done, they can change it at their own expense. The decree should be right at first, and, therefore, when I say initiatory steps, I mean those steps necessary to secure protection in this respect.

I believe that a city seeking a just settlement of a grade crossing problem can secure the best results by placing the matter in the hands of a commission consisting of the city engineer and the railroad engineer, and one other appointed by them. If the report of these experts is satisfactory, and if their plan is finally adopted by the Special Commission appointed by the Court, the decree of the latter should contain verbatim the detailed specifications prepared by the former. By this method, I can hope to see satisfactory changes made in crossings at grade of city highways and railroads, and by this method only can I hope to see the positive security of the vital interests of a community which alone warrants procedure in so important a public work.

(*b*) The Plans Adopted.

By James W. Rollins, Jr., Engineer for the Old Colony R. R. Co.

[Read December 19, 1894.]

Much of the following is taken from an article prepared by the present writer for the *Railroad Gazette* and published in that journal early in 1894.

Brockton is a city of about 30,000 inhabitants, on the main line of the Central Division of the Old Colony Railroad. The growth of the city has been one of the largest among Massachusetts towns: a town in 1821, a city in 1881, and increasing from 13,000 inhabitants in 1880 to 30,000 at the present time, as above stated. Within the city limits are three stations, with freight yards and houses—Montello, Brockton and Campello. As in most manufacturing towns, the growth has been along

the line of the railroad; gradually streets have been laid out across its tracks, all at grade; and private ways and farm crossings have become public ways, so that at the present time there are eleven crossings at grade over which the public have rights. The freight yard at Brockton is at present in the center of the city and freight cars have to be shifted across the principal streets.

When the grade crossing law was passed, in 1890, Brockton was the first city to avail herself of it, and immediately petitioned for a commission to be appointed in accordance with the provisions of the act and also began negotiations with the railroad officials regarding the abolition of all the grade crossings within the city limits. The act of 1890 provided only for public streets, and, as many of the most important streets in Brockton had never been accepted as public ways, a special act was passed in 1892 permitting the Commission to consider private ways. Various schemes were presented and discussed, and finally an agreement was made between the city and the railroad, in June, 1893, to raise the grade of the railroad through the center of the city 12 feet and to depress it through Campello about 8 feet.

One of the worst complications was the question of freight facilities at Brockton. A short time before, the railroad company had bought a piece of land of about 15 acres for a freight yard. This land is some 15 feet below the grade of the tracks as they now are, and to get down into this yard from a grade 12 feet higher necessitated raising the whole yard some 10 feet, and building, across the main streets, switching tracks supported by heavy retaining walls.

While the affairs incident to the change of management from the Old Colony to the New York, New Haven & Hartford were being straightened out, the plans described above were changed, and entrance to this freight yard, to which had been added some 20 acres more of land, was made from the north side at a great benefit to the yard, and great saving of expense in extra tracks and walls through the city. These plans, now adopted, call for the following changes and work:

The grade of the railroad is to be raised, for a distance of 9,000 feet, the maximum rise being 15 feet, and lowered for a distance of 5,100 feet, the maximum being 12 feet. Four tracks are to be built throughout the length of this change of grade; new passenger stations are to be built at Brockton and Campello, and a new waiting station at Montello, all from plans of Bradford L. Gilbert, of New York City, who has made the plans for most of the recent stations on the Old Colony road.

All stations will be double, consisting of a main station on the west side of the tracks (trains run toward Boston on the west track), with a waiting station on the east side. Subways under the tracks

connect the two. The Brockton main station will be 33 feet by 140 feet, and the waiting station 30 feet by 104 feet. This main station will be on the grade of the tracks, and the approaches will be graded to it, so that carriages can drive up to the platforms. A walk leads from the main street to the subway, which continues through under the station and tracks, on a level, to the waiting station on the east side. All the stations are to be built of granite, with red sandstone trimmings.

At Campello, which is the terminal for a series of local trains, the present terminal grounds, with engine-house, turntable and coal sheds, will be taken and used for the new passenger-station grounds, and a new terminal will be provided, about 1,500 feet south of the present one. For this terminal a tract of land of about seven acres will be taken, admirably fitted for such a purpose. It is dry and has a gravelly soil, which can be easily drained. On this will be built a 70-foot brick engine-house with four stalls, a 60-foot iron turntable and a coaling trestle, with all necessary tracks, sidings and connections.

This change of grade, as decided upon, will require the construction of seven arches of masonry over streets, two arches over streams, four subways for pedestrians, three of which are between stations, as before described, two plate-girder bridges, also over streets, and eight highway bridges over the railroad.

Three of the street arches have a span of 50 feet, with rises of 7, 8 and 9½ feet respectively, and two with spans of 41.25 feet, with rises of 6½, and 7 feet; the other two arches are 30-foot spans, practically semicircular. All arches, except the two latter, have walls 7 feet high above the sidewalk, at the ends of the arches. To overcome the difficulty and expense of these flat arches, the arch sheeting, with the exception of about 3 feet at each end of the arch, is continued down to skew-backs almost at the street level, so changing the ratio of span to rise in the worst case from 7 to 1 down to about 5 to 1. This changes the angle of the resultant of the combined loads so as to bring it within the middle third of the foundations, designed to carry a load of 3 tons per square foot, which is the limit allowed for these structures, the soil being good, firm gravel, and the masonry foundation 4 feet of concrete. The faces of these arches will show an arch springing from a skewback, 7 feet above the street grade and on the street line, but this skewback and wall supporting it will be only 3 or 4 feet thick, and then the arch will drop back as stated. It is proposed to build an ornamental iron fence on the line of the walls, *i.e.*, the street line, on a heavy curbstone, to keep the public within the street limits.

The backing of all the arches will be of concrete; and to make this water-tight it is proposed to cover this backing with three thicknesses of heavy roofing paper, each lapped one foot and thoroughly tarred over,

with an inch of asphalt over the paper. The water will be collected in gutters to be built in the edges of the concrete backing, and from them conducted through the masonry by pipes into the street drains. Only two of the five main arches are square, the balance being at angles varying from 83 degrees to 57 degrees. It is proposed to make the ring stones of these arches of granite, in courses parallel to the axis of the arch, with the faces cut on the skew required, with possibly the exception of the worst angle, which may be built with a true skew face with arch inside of brick.

Plate-girder bridges will be built to span Ashland and Lawrence streets, the former requiring girders 57.5 feet long, and the latter girders 47.5 feet in length. These bridges will be built of wrought iron, with floor beams, supporting track stringers, which are spaced 6 feet apart on centers. On these stringers will be the floor, of 8 x 8 inch ties, 13 feet long, spaced 4 inches apart, and guard-rails of 8 x 8 inch timber, notched to 6 inches outside of track, and rail-guards inside of track. These bridges are to have a plank floor on the ties, to protect the travel in the street below.

All masonry supporting track bridges is to be of first-class ashlar. Highway bridges will be riveted lattice trusses, with suspended floor beams between tracks. Trusses will be about 7¾ feet in height for 70 feet spans, or generally about one-ninth of span, and will carry a side-walk on both sides of the roadway. The floor of the roadway is of double planking, 3-inch hard pine underneath, on 4 x 14 inch hard pine floor stringers, and 2-inch spruce planking on top, forming surface of roadway. Bridges are designed to carry a load of 100 pounds per square foot, or two 24-ton electric cars, coupled, or side by side on two tracks. The masonry supporting highway bridges will be of first-class rubble, laid solid in cement mortar.

Extensive facilities have been provided for the freight traffic, comprising three main yards, with numerous side tracks, all to be provided with the best and latest improvements as to frogs, switches and signals.

These yards have a combined area of about sixty acres, with a capacity of 2,000 cars.

While such yards and capacity will not be needed for a long time, it was thought best to secure the land now. This consists of large undeveloped areas, near the tracks or the existing yards, which, in the great probable development of Brockton, might be entirely unobtainable ten years later. These yards will be graded only at present to such an extent as to provide for the next ten years' business.

The main freight yard will be at Brockton, and will have an area of about forty acres.

The grade of the yard, when finished, will be 24 feet below the

grade of the tracks as raised, and, to get into the yard from the main tracks, a switchback will be used. This switchback will be double-tracked, and will be in part on an 8 degree curve and on a grade of 1¼ per cent., 1,700 feet long, terminating at the switch, from which the tracks run back into the yard. From this switch the main tracks continue about 800 feet eastward, as switching tracks, or tail tracks, on an ascending grade of 0.5 per cent. These tracks will give room for handling a train of 20 cars.

The tracks running back from the switch above mentioned, will have a grade of 0.6 per cent. covering a descent of 4 feet into the main yard, and to the freight houses. This yard could be operated by gravity were there any assurance as to the conditions of the brakes on the cars. Cars would run down the 1.2 per cent. grade for 1,700 feet, then strike an ascending grade of 0.5 per cent., 1,100 feet long, on which the momentum of the car could be stopped. After being stopped the car would run back down the 0.4 per cent. grade to the switch in the main freight tracks, thence back into the yard on a down grade of 0.6 per cent. on to any one of the tracks there, or to the freight house.

Special effort will be made to drain the main yard, and it is believed that this can be done by sloping the yard transversely, or north and south, on a grade of about 0.5 per cent. to the center, there collecting the water into catch-basins, which will empty into a [city] drain running through the yard, the drain being low enough to provide sufficient fall.

All switching will be done on the high-grade tracks, so that freight *trains* will not enter the yard at all, the work of shifting the cars up and down the grade into the yard being done by a switching engine.

New freight houses, 25 feet in width and 500 to 600 feet in length, will be built in this yard, probably one for shipping and one for receiving freight. A coal shed 80 feet wide, for a double track, and some 500 feet in length, with a capacity of 25,000 tons, will be built on the west end of the yard, adjoining the main line.

Entrances will be made to the yard on three sides, giving excellent facilities for shippers to get to and from the freight houses. One of these entrances will be through an arch of 30 feet span and 16 feet clear head room, under 9 tracks, 4 main and 5 side tracks.

At Montello and Campello, yards of about ten acres in each, will be graded, and onto these yards the present freight houses will be moved.

Through each of these three freight yards is a water-course—the main drainage of that section of the country. At Montello is an 8-foot arch, with 3-foot walls, 700 feet long; at Brockton, a 16-foot arch, with 6-foot walls, 140 feet long, and at Campello, a double 16-foot arch with 5-foot walls, 160 feet long.

The arches are, in all cases, of brick, the side walls of rubble masonry, and the invert and foundations for walls, of concrete. In two cases the foundations for these arches are known to be good, but at Campello, it may be in quicksand, though the depth of the excavation is not over 6 feet below the level of the ground, so that no great difficulty is anticipated.

The grade of the Brockton freight yard culvert is 17 feet below the level of the yard, but, as the whole channel of the stream is changed there, only the seepage of the ground and river water will be troublesome. This culvert is 5 feet deeper than the adjacent channels, being put down to the proposed grade, as established by the city of Brockton. A branch of the main water-course crosses the present tracks of the railroad just south of Crescent Street, through an opening of about 24 feet, spanned now by girders. This channel will be lowered about two feet, and an arch of 22 feet span, with 5-foot walls, will be built to convey the stream.

This arch and the adjoining retaining walls, made the heaviest piece of masonry in the whole scheme, the walls being 30 feet from foundation to grade, and 200 feet long. As the limits of the right of way here are about 70 feet, and on both sides are new walls 20 feet high, which must be rebuilt, and as the railroad traffic must be maintained, this piece of construction will be about the most difficult to handle of any.

The proposed method of construction is to build two temporary tracks on the limit of the land acquired, on the east side of the tracks at the present grade, for operating the road; the freight traffic, switching, etc., having been provided for in the new freight yard now well along in its construction. This will keep the freight traffic clear of the operating tracks. As arches are to be built at all the main crossings, the centering for masonry will block the street, but it is proposed to build one arch, or enough of it to get two tracks across, at a time and leave the adjoining streets open. As there are five crossings within 1800 feet, the inconvenience to the public (teaming and electric cars only, for provision for foot travel will probably be made under centers and timbering) will not be great; but as the streets are to be lowered from 2 to 7 feet within this distance, and as the finished clearances are to be from 13 to 16 feet, the head room will be reduced to about 10 feet until the traffic is turned onto the two high tracks. While these high tracks, and the walls and arches, are being built, the west and main passenger station, with its grounds and approaches, will be constructed, so that when the traffic is turned onto the high grade the new station will be in readiness. In most cases we have land enough to build two tracks, allowing for full slopes, but where we are limited we shall either put the high tracks upon a trestle, or crib up the slope from the high grade to clear the low

tracks. Where the tracks are to be lowered, the cuts (all sand) will be widened out on the west side to the true slope at the present grade, and two tracks will be thrown over as far as possible in the new cut. Then, with teams or by train, the east side of the cut can be taken out to the low grade and wide enough for two tracks, which will be laid there and the traffic turned thereon, after which the rest of the cut will be taken out.

Throughout this lowering, with the exception of some 150 feet, we have acquired land enough for the full slope. The material, some 150,000 yards, excavated in this cut, will be hauled into the adjoining streets, which are to be raised or replaced with new ones, or into the embankments or freight yards.

Many changes are to be made in the grades of the streets, every one of those crossed being changed, to get over or under the railroad, and these changes of grades in many cases will involve other streets adjacent to the grade crossing abolished. These changes are in most cases such as to necessitate the reconstruction of the water and gas pipes and sewers, and in many cases the construction of new drains for the disposal of water, which will be changed in its flow by the changes of grade.

All these streets are to be either paved with granite blocks, or to have a macadam paving 8 inches thick, with edge stones, crossing, etc. The decree of the Commissioners requiring this work to be done, "for the security and convenience of the public," was signed on March 8, 1894, and it is expected that the work, already begun, will be finished within three years. The estimated cost is $1,500,000, of which amount the railroad pays 65 per cent., the State 25 per cent., and the city of Brockton 10 per cent. The Commissioners, appointed by the Court, under whose direction the plans for this work have been made, were Hon. B. W. Harris, of Bridgewater; Charles B. Barnes, of Boston, and H. C. Southworth, C. E., of Stoughton. The engineering has been done by F. H. Snow, City Engineer, for the city of Brockton. Plans of stations have been prepared in the office ot Bradford L. Gilbert, of New York; and the Old Colony work has been done by the writer.

ABOLITION OF GRADE CROSSINGS ON THE PROVIDENCE DIVISION OF THE OLD COLONY RAILROAD IN BOSTON.

By James W. Rollins, Jr., Engineer for the Railroad Company.

[Read December 19, 1894.]

The abolition of the grade crossings on the main line of the Providence Division, in the city of Boston, will require the elevation of the tracks of the railroad; beginning at Massachusetts Avenue, thence rising on a 0.6 per cent. grade to an elevation of 18 feet above existing tracks at Roxbury Station; this elevation is maintained, from 18 to 20 feet, to Washington Street, Forest Hills, where the grade begins to descend to meet the old grade some 3,000 feet south—the new grade of the West Roxbury Branch runs out at the Bussey farm arch some 2,000 feet from the junction at Forest Hills.

This involves a change of 4½ miles of road, over which on three tracks, is now handled a daily train service of 186 regular trains, besides numerous "extras." Generally this raised grade will clear the highways, although Ruggles Street, being only 3,700 feet from the beginning of the change, will have to be lowered 4½ feet. The lowering of this street will necessitate the changing of the Stony Brook conduit which crosses the railroad in Ruggles Street in two 8-foot arches, and has various connections, tide-gates, etc., so close as to be involved in the lowering of the grade of the street.

It is proposed to substitute five 48-inch pipes for these two arches, and, in that manner, gain the necessary head room.

Tremont Street, at the Roxbury crossing, will be lowered two feet and spanned with a steel arch of a span of 80 feet.

Somewhat similar arches are proposed at Morton and Walk Hill Streets, at Forest Hills, and the rest of the bridges are plate-girder deck bridges, with solid iron floors covered with concrete and ballast, and are to be water-tight. Twelve grade crossings are abolished. Centre Street at Hogg's bridge, now an overhead crossing, will be lowered 18 feet, and the railroad will be carried over it. Two new streets are provided for in the elevation—Mozart Street, just north of Boylston Station, and William Street, between Green and Keyes Streets, at Forest Hills.

In addition to these, the Park Commission of the city of Boston will build a bridge under the tracks, as raised, just north of Morton Street at Forest Hills.

This bridge, as shown by preliminary sketches, will consist of three

arches—one 44 feet, and two 22 feet, in clear span at right angles to the street line, finished with a heavy and ornamental coping and railing, which makes a very massive and handsome structure.

Subways will be built between stations, thus making a total of 15 street crossings, 5 subways, and the park-way arches, as above described, to be built under the change.

The plans, as signed by the Commissioners, show retaining walls to be built, from Prentiss Street to Old Heath Street, on both sides of the track; and from Boylston Street to Green Street, on the west side; and from Green Street to Keyes Street, on the east side, with short lengths in various other places to protect station-grounds and private property.

For the rest of the distance, land has been taken for slopes.

These retaining walls will require more than 100.000 cubic yards of masonry, which, together with the various other constructions, will make an aggregate of at least 125,000 cubic yards. The filling required will exceed one million yards.

The plans, as originally signed and filed early in 1893, maintained the railroad in its elevated grade, clear of Stony Brook which runs close to the tracks for 2,700 feet near Boylston Station, and 1,800 feet south of Forest Hills on the West Roxbury branch.

This construction required heavy retaining walls, and left the brook in its old location and grade, to be rebuilt later by the city of Boston when the change of that troublesome stream should be made to the low grade, as reported upon by the Commission in 1889.

By agreement with the parties in interest, a change was made in the plans where Stony Brook was involved, whereby the railroad company took extensive areas of land—enough to admit of moving the brook over far enough from the railroad to permit its being reconstructed on the new low grade, which is 13 feet lower than the present grade, and, also, to clear the slope of the railroad. The section to be rebuilt, near Boylston Station, some 2,700 feet long, is a 15½ x 17 foot brick conduit, with concrete invert lined with brick, and with rubble masonry backing.

Borings showed all kinds of material to be met with in the excavation. Hard-pan at the north end (which the excavation has developed into a rotten rock), then a section of 700 or 800 feet of quicksand, the cutting being about 22 feet deep, then a like distance of hard-pan or rock—probably the latter, in a cutting from 25 to 37 feet deep. The new channel is from 7 to 20 feet from the old channel, which is open, with side walls of Roxbury pudding-stone, laid up dry.

The net cost of this Stony Brook construction is materially lessened by the fact that the surplus material is put into the railroad

embankment, and so, practically, costs nothing, embankment only being estimated for the railroad work. It is to be hoped that when this section of the improved channel is completed, Stony Brook will be in its grave, for the struggles that the old town of West Roxbury, and later the city of Boston, have had with it have been many and costly, and must often have led the authorities who had to deal with it, and the taxpayers who had to pay for that "deal," to wish that the recommendation of some Boston aldermen "to discontinue the ——— brook," might long ago have been adopted.

At Forest Hills, a section some 270 feet in length, a double 8-foot conduit will be built, and from there to the end of the change an open channel outside the slope of the railroad in its high grade.

The station arrangement is, in all cases, for a double station, connected by subways. Waiting-rooms are, with the exception of Roxbury, on the grade of the elevated tracks, and have stairways to the street level; as have also the platforms which are generally 15 feet wide at the station, and for about 200 feet each side; beyond this to a total length of 600 or 700 feet they are 7 feet in width.

Express trains are to run on the two inside tracks, and these tracks will be fenced off so that there will be no crossing of track at grade, and passengers alighting from local trains will be in no danger from the express trains which can then run regardless of locals and of their passengers.

All freight tracks now in use will be abandoned on the elevated grade, and, in substitution for them, quite an extensive yard is laid out on Lamartine Street from Centre Street almost to Boylston Station. This yard can hold 100 cars, and has tracks outside the main line on which to do all shifting.

The estimated cost of this work is about \$3,500,000, of which the Old Colony Railroad pays 55 per cent. or \$1,925,000, the city of Boston \$472,500, and the State \$1,102,500.

This work being done under a special Act of the Legislature, the State's proportion amounting to \$1,102,500 does not come out of the five million which, under the Act of 1890, is the limit of the State's share.

DISCUSSION.

Mr. Charles A. Allen.—I have been very much interested in Mr. Rollins' description of the work to be done on the Providence Division of the N. Y., N. H. and H. R. R., and at Brockton, because, as far as I know, they are the first two comprehensive schemes for carrying out the abolition of grade crossings where more than one or two crossings are directly concerned.

When the Act of 1890 was first passed by the Legislature, the tendency, especially on the part of the engineers representing the cities and towns, and on the part of the town authorities, was, to look upon the different streets in cities and towns as being independent of each other, and as furnishing problems which could be solved independently of one another. This was very soon found to be a mistake, and, as a consequence, very much work that would otherwise have been done in the abolition of grade crossings has been delayed, and I think for very good reasons indeed.

I have been asked to say something in relation to matters we have had under consideration at Northampton, and, as it is in a direct line with the sentiment expressed, that crossings in the cities and towns are often more or less intimately connected, I will say a few words on that subject.

Very soon after the Act of 1890 was passed, for the gradual abolition of grade crossings throughout the State, a petition was filed with the Superior Court for the appointment of a commission to consider the matter of the abolition of the grade crossings at Northampton. The city authorities had little idea of what was required.

A commission of three gentlemen was appointed, one of whom was Mr. E. K. Turner, formerly the Chief Engineer of the Fitchburg Railroad.

The plan presented by the Connecticut River Railroad, then an independent line, was to carry the streets over the railroad without much change of grade of the tracks. This plan was not popular in Northampton, and the city authorities very soon saw that they would need some one to assist them in the matter. They employed the late Augustus W. Locke, then a very able member of this Society, and also a very able and intelligent engineer; and he devised a scheme for elevating the railroad tracks and depressing the streets. This plan did not provide for changes in the location of freight yards, but was necessarily a very hastily devised scheme, but it was presented to the Commissioners. They had a number of hearings, and at this time I was called into the case.

After a somewhat hasty study of the question, as the time was limited, it seemed to me that the plan proposed by Mr. Locke was the best one. This plan was presented to the Commissioners, but they adopted the plan presented by the Connecticut River Railroad. The decree was reported to the Court, but was contested by the city. The Court, however, confirmed the decree.

The city then went to the Legislature for relief, and had a bill passed which I think is unique in the legislation of this State, or in any other State for that matter. It provided that no street grades should be

changed except with the consent of the City Council. It virtually set aside a decree of the Superior Court, and it was considered by many eminent lawyers to be unconstitutional. It was taken to the Supreme Court and very ably argued by both sides. The Supreme Court decided that it was constitutional, and that the Act must stand. The parties interested were thus left in a position where the city could not move because it could not change the location of the tracks, and the railroad could not move because they could not change the grade of the streets.

It was very soon found that some arrangement must be made to bring about an agreement in the matter, so a meeting at Springfield was arranged with the railroad officials, and it was agreed that if Mr. Curtis, Chief Engineer of the N. Y., N. H. and H. R. R., Mr. Bissell, Chief Engineer of the Boston and Maine Railroad, and Mr. Locke would agree upon a plan it would probably be adopted. In going from one of the meetings held following this decision, Mr. Locke caught a very severe cold, and it was the last time he appeared, for his illness terminated fatally. Having been more or less mixed up in the matter, I was called in to take his place.

Very soon after this a meeting of the engineers was held and work was begun in earnest upon the plans, with the result that a scheme was developed which provided for elevating the tracks and for the construction of a new Union Station, a new engine house and new freight yards, at the northern end of the city.

The original decree was referred back to the Commission within a week, and I presume that very soon the question will be settled so far as Northampton is concerned, and, I think, in a very admirable way.

These are the difficulties we labored under in the settlement of this question, and it calls out the point I wished to call attention to, as suggested to me by Mr. Rollins' paper, although it seems almost absurd to suggest this at a meeting of engineers. It is this: that plans for the abolition of grade crossings in cities and towns, like those for the construction of waterworks or sewerage systems, should always be thoroughly considered before a decision is arrived at.

I have had the honor to be connected with a number of these questions throughout the State. Among them I call to mind at this time the matter of the abolition of the grade crossings in the city of Newton.

The Boston and Albany Railroad officials devised a plan for the elevation of their tracks on their present location, and, after a very careful study of the matter, we reported in favor of the same plan. It seemed to be the best thing to be done under the circumstances, but there is this difference between us: I thoroughly believe, and I have advocated, that we should have much better work in the way of bridge construction. I do not mean that the bridges should be built in a more

substantial manner, but that more attention should be given to architectural and artistic effects in constructing bridges, more particularly in the populous parts of the country, and especially in cities as large as Newton and Worcester. I know that a great many engineers do not agree with me in this matter. I think, however, the reason is, that the railroads have a very large portion of the expense to pay, and perhaps there is a great deal to be said in favor of their position. The cities and towns pay but 10 per cent. of the expense of construction, and, if anything more than strength is required, I think they should pay a larger portion of the additional expense. I do not think the railroads should be called upon to pay anything more than is required to construct a bridge in a thorough manner. I am very glad to see in these two cases, of which the details have been presented by Mr. Rollins, that a very decided step has been taken in the right direction. As I understand it, the bridges on the Providence Division are to be steel arches, with some masonry arches, and at Brockton masonry arches are to be used almost entirely. I believe this is right, and where it can be done it should be done.

I have examined a great many bridges of all descriptions, both in this country and abroad, and I am obliged to say that for architectural effect our bridges are not to be compared with those spanning highways in France, Germany and England. I understand that the latter have been built under circumstances different from those we have here, but I think our cities and towns ought to pay, in addition to the amount required to build a strong, substantial structure, a sum sufficient to make it at least presentable.

In his paper Mr. Rollins has referred to the construction of electric roads crossing railroads at grade. It seems to me that this is positively the most dangerous thing that can be done. I do not think it should be permitted under any circumstances, except as a temporary measure.

We have had all over the State very many escapes from bad accidents due to this method of crossing. In Worcester, a short time ago, a car loaded with passengers stopped on the railroad track while crossing, as the electric current gave out. An express train was approaching rapidly. This train was stopped barely ten yards from the car. Most of the people on the car were too terrified to move, and a terrible accident would have happened had the train struck that car, even at a low rate of speed. Accidents are liable to happen at almost any time in a similar manner. Look at the accident at Southbridge. I have heard it stated that this crossing ought to be abolished, but after the town found that it would have to stand 10 per cent. of the cost of its abolition, nothing further was heard of it, and it was thought that perhaps it was not a very bad crossing after all, because no one had ever been injured there. This argument is very often used.

It is, of course, a very serious question where the money is coming from to abolish all the grade crossings in the State, and it is not to be supposed that the railroad corporations will rush into the matter any faster than they feel they are obliged to. It means to them, to the State, and to the cities and towns, the expenditure of an immense amount of money. We are moving in the right direction, however, and the grade crossing has got to go. The only thing to do is to take hold of these questions as they come up, and then settle them in the very admirable way in which the questions before us have been settled by the engineers in charge of the Boston and the Brockton matters.

Mr. John W. Ellis.—The elimination of grade crossings is a question of very grave interest and importance to every engineer, and one that calls for engineering skill, experience and careful study. In the matter of electric railroads, no other element is, perhaps, of more importance. A railroad, with steam for motive power, crosses a highway, and is condemned as a nuisance, but the street railway, with electricity as a motive power, runs parallel to the railroad on the highway. I call such an arrangement a street railway grade crossing throughout its whole length.

It has been my good fortune to act as engineer in several instances for the elimination of grade crossings in all its phases, as consulting engineer for railroads, cities and towns, and it seems to me that, on the average, the railroads are compelled to bear the brunt of the expense of the necessary changes. I am stating things generally, not specifically. The railroads are very likely to look to the necessary expense of the improvement rather than to the public convenience; the public looks to the appearance of the work, rather than to its practicability taken as a whole, while outside parties sometimes present, in their own interests, plans based more or less on speculation. In order to make a fair and impartial decision, we must take all these things into consideration and present them to the engineer and to the commissioners; and a proper solution of the problem requires the most careful examination of the details presented. You must consider the matter thoroughly and deliberately before you can be ready to grasp the question and settle the problem.

In Providence, a satisfactory agreement between the city and the N. Y., N. H. & H. R. R. was made in regard to the grade crossings north of the terminals. I think it was proposed, when the Legislature came in session, to pass a grade crossing law, but it seems now to be the general opinion that it is good policy to learn wisdom from your State. A reasonable time should be spent by the parties in interest, to see if they cannot agree, and they should not be allowed a commission until they have formulated a plan that they would wish to present to the commissioners when they are appointed.

Mr. Rollins' statement of the proposed changes of grade on the Providence Division has greatly interested me. If, on this question of the elevation of the tracks, and in the capacity of Inspector on the Old Colony Railroad, the Directors had asked me what effect I thought it would have on the property of the Providence Division, I would have replied that I did not think that came within the scope of the engineer. But it is quite a serious question whether the suburban travel would or would not take the electric cars in preference to it. Then, too, consideration should be given to the decrease of value which is liable to occur to the lessors in this case, who are held responsible by the stockholders to see that the value of the property does not depreciate.

Mr. F. Herbert Snow.—I have listened attentively to all that has been said, but I have listened with the consciousness that for me, as a city engineer, it is impossible to look at the subject of the abolition of grade crossings from the standpoint of the railroad engineer. From the moment a scheme is started until everything is settled these engineers work upon widely different premises. Each will labor to save the money of his employer, and just so far as the city's interests and those of the railroad are at variance, just so far will their respective engineers be divided in their opinions.

Mr. Rollins has given us some substantial reasons why the head room of under-passes should be kept down to the minimum, but should these reasons be controlling ones?

I admit that in a discussion of this question the city engineer labors under a disadvantage. The arguments of the railroad engineer will be presented, with facts and figures hard to controvert, and they will, I am forced to believe, be likely to prevail; nevertheless, I submit that the question of head room ought not always to be settled upon the basis of the greatest economy to the railroad company. Why should it follow, because a project to abolish the grade crossings of a community must necessarily involve the expenditure of a large sum of money, that economy must be practiced chiefly at the highways.

It seems to me an erroneous idea that the only object to be sought and attained in the abolition of grade crossings is their riddance. There is a greater object, and it is found in the broad interpretation of the term public improvement. I argue that the abolition of grade crossings is a public improvement in the sense that the State recognizes it to be such, and (since such public works exert a positive influence upon the development of the varied interests of a city) if the diversified interests, present or prospective, of any community are to be given, as they should be, an opportunity for full and unrestricted growth, the abolition of the grade crossings should be so conducted as to provide, as far as possible, for that growth. Hence the desirability of liberal head room for under-passes.

This question can be definitely settled by the Legislature, and, since the clearance of bridges where a highway passes over the railroad is regulated by statute, it may be well to regulate in the same way the clearance where a railroad is to pass over a highway, fixing a minimum height for all cases.

In all that has been said in relation to stone arch bridges I can most heartily concur; and, furthermore, I would like to make a plea for the principles of beauty in engineering architecture.

It is to be regretted that those in authority have sacrificed these principles to economy in those Brockton stone arches, where there was a favorable opportunity and real need for the application of architectural symmetry and ornamentation.

I believe that sentiment should not be left wholly out of consideration in public works of this kind. If it is true, as many claim, that the influence of architectural beauty, even in a stone arch bridge spanning a highway, acts upon all classes as an incentive to improvement; if it increases the attractiveness of the city, making it more desirable to reside in by thus adding to its respectability, then I am supported in my belief that towns and cities and, above all, the State should encourage and promote the principles of beauty in engineering architecture.

I am not unmindful of the fact that a railroad company is a money-making corporation, and hence its opposition to any plan or principle involving the expenditure of money not required for practical purposes must be expected. But this natural and proper opposition ought not to deter the town or city engineer from his duty. With him the question is not, what proportion of the entire cost of abolishing the grade crossings the town or city is to pay. His duty is the same, whether the town or city pays the whole cost or none of it.

It is pertinent to this line of thought to touch upon the question of the extent to which the people of any particular place can legally be interested in the plans for the abolition of its grade crossings. As the subject is now understood, the Superior Court decrees what shall be done; a commission is appointed to give hearings as to the necessity of the abolishment as asked for in the petition of the selectmen, the mayor or the president of the railroad company. At the hearing or hearings the public has an opportunity to be heard. If I am correct, as soon as the commission decides that public necessity does require an abolishment of the crossings, it proceeds to determine the manner and limits in which the work shall be done, and this it has a right to do without consulting the public. This being the fact, there is no opportunity for individual remonstrance to the plans. This is a good thing in some respects and a very bad thing in other respects. Even the right of the mayor to remonstrate effectually is debatable, so that it becomes a vexed question

for the city engineer to decide to what extent he is connected with the proceeding when he is instructed by the mayor to look out for the engineering interests of the city. Of course, the railroad officials will not fail to keep constantly before him the fact that the city pays but 10 per cent. of the entire cost.

The subject of land and grade damage has been an important one at Brockton. I was called upon to prepare plans and estimates of the cost of abolishing the grade crossings of a place where the development of adjoining property had been governed and controlled largely by its relation to the elevation and location of the railroad and by the privileges thus afforded, and where the rents of buildings and the values of land have come to depend upon the custom of the public to take particular streets or avenues in passing to and from passenger stations, upon grade crossings, and upon other facts which entered largely into the problem. In summing up the items of cost, I found the item of land and grade damage to be a large one.

This will be more or less true in other cities. But the engineer is most concerned, not in the extent of the item, but in its correctness, and I do not hesitate to say that no matter how much care has been exercised in studying details and estimating damages to every estate affected, or whether or not the engineer has anything to do with the final settlement of the claims, that one item will cause him more trouble than all others put together.

If the engineer is appointed to settle claims, he will be impressed with the manifold difficulties of the work before he has fairly made a beginning, and if higher authorities decide that the settlement of claims is not necessarily an engineer's work, and if others are appointed to do it, without the consent and knowledge of the engineer, his estimates are likely to be largely exceeded, and his judgment and competency brought into question.

After the preliminary plans of the Brockton scheme were agreed upon by all parties in interest, the railroad engineer and the city engineer took up separately the details of all those parts of the work in which their respective principals were most directly concerned, and upon the joint estimates submitted by the engineers the whole project was based. In making estimates of damages, great care was taken, and much time and special study were given to over 250 cases, in order to obtain estimates which should be fair, and yet large enough to allow for a liberal settlement.

We had good and sufficient reasons for every case and estimate, and we had confidently hoped, after having taken these infinite pains, that settlements could be effected in or out of Court upon the basis of our estimates. These estimates have not controlled in settlements,

and, while I do not find fault, nor in any way criticise the judgment of those who have been appointed and are zealously discharging the duties intrusted to them, I do criticise the railroad company for not allowing its engineer a voice in the matter of settlements.

The railroad company, which, by the decree of the Court in Brockton's case, is to do all the work—the city engineer directing that part of it in and under the highways—had to rely on the judgment of the engineers in the first place; and since the company decided to settle, out of Court, as many cases as possible, the least it could have done in fairness to the engineers was to allow them a chance to substantiate their estimates before settlements were made. Under these conditions you can readily conceive how an engineer could be more worried and perplexed and hindered than if the whole job of adjusting damage claims devolved upon him. I say, therefore, to the city engineer: Look out for the correctness of the item of land and grade damage, and do your best to secure a voice, either for the railroad engineer or for yourself, in the settlement of claims.

Right in this connection I might refer to those parties owning business properties adjacent to and depending upon the railroad and its facilities, who cannot recover damages, really serious in some cases, resulting from the elevation or depression of the railroad tracks. The railroad company claims the right to elevate or depress its road-bed without considering the consequent damages to abutting properties, but I ask this question: Since public interest requires the railroad company to alter the conditions under which thousands of dollars have been invested in developing and equipping private property, with facilities for doing business with the railroad, and since these alterations—called for by public necessity—cause serious damage to these private properties, would not a claim for compensation here be as valid as that for damages to estates abutting on a highway where changes in grade are made?

Mr. George A. Kimball.—I have been much interested in Mr. Rollins' description of the proposed changes at Brockton and in Boston on the Providence Division of the New York, New Haven & Hartford Railroad. Both of these improvements were recommended in 1889 by the Grade Crossing Commission, of which the late Mr. Locke was chairman.

I wish to add my testimony to that of Mr. Allen in regard to the importance of considering these questions in a comprehensive manner, as has been done in these two cases. To mature plans of this magnitude requires careful and patient negotiation. The plans presented this evening are the result of nearly five years of study and negotiation between the parties interested. The results are a credit to the officials of the cities and of the railroad company.

Years ago engineers would hardly have dared to recommend such marked changes in the grade of the railroad as are proposed in the two improvements described. I think it was twenty years ago when the matter of raising the railroad tracks came up in Springfield. At that time the County Commissioners decided to separate the grades, and they sent in a decree demanding that the railroad companies raise their tracks, substantially as they have now done. This was opposed by the railroad companies and was finally sent to the Supreme Court. The Court decided that the County Commissioners could not compel the railroad companies to raise their tracks. The decree of the court is contained in the Massachusetts Report 116, page 78, and a portion of it reads as follows:— "The much greater weight and speed of the engines and cars moved by steam upon a railroad, than of the wagons and carriages traveling upon an ordinary highway, render it necessary that the railroad should be constructed nearly upon a level, and make it much more practicable, in accommodating the necessities of the one to those of the other, to vary the grade of the highway than that of the railroad."

The decision was made in the year 1874, and we find that a few years later the railroads voluntarily raised their tracks and built a beautiful stone arch bridge over Main Street.

In making these improvements I would be glad to see more substantial masonry arch bridges built instead of the common iron bridges which are usually erected. The stone arch can be made to please the eye, and, when once built, it is good for a great many years with little expense for repairs. The Pennsylvania Railroad Company's Chief Engineer writes me that iron bridges do not last more than ten or fifteen years under their traffic, no matter how heavy they are built. They constantly need painting, new floor, etc. They have masonry arch bridges forty years old, that have not required more than forty dollars for repairs in fifteen years.

THE LIBRARY.

It is proposed to notice briefly, in this department of the JOURNAL, such engineering publications as may find their way to our shelves.

Publishers are requested, in sending works for review, to state the prices of same.

L'Esposizione ed i Congressi di Chicago, NEL 1893. By Cav. Ing. Celso Capacci. Florence. 1894.

Those who had the good fortune to meet Cav. Capacci during his visit to this country and to the World's Fair will note with interest the appearance of this report, in which he describes the impressions gained here.

A dozen pages are devoted to a description of New York City and its various points of interest, and half as many to a brief account of the three principal national engineering societies. As the exhibition itself is handled in thirty-three pages, and the International Congress in fourteen more, it will be readily understood that our author has not undertaken to give to his compatriots more than a superficial view of the great exhibition. Three pages are devoted to California, and a table of a few of the more common English measures, with their metrical equivalents, is given.

Diatoms in Surface Waters. SOME OBSERVATIONS ON THE GROWTH OF ——. By George C. Whipple, S.B., Biologist in charge of Laboratory of the Boston Water Works, Biologist of the Water Works of Lynn. Reprint from the *Technology Quarterly*, October, 1894.

If an engineer in these late days is ever tempted to imagine that he knows it all, such works as these, showing how largely he is dependent upon specialists in other lines, ought to correct the error.

Mr. Whipple, after briefly referring to the very complete system of work at the Boston Laboratory, defines diatoms as minute plants forming a group of microscopic algæ, containing over one hundred genera, of which, however, not more than twenty are commonly found in our water supplies, and only six have thus far been found to be of practical importance.

Except that "Asterionella is the diatom which is most active in producing tastes and odors in the water," we do not find that our author states to what extent these growths are injurious to a water supply. He does, however, urge the importance of removing the top soil when preparing a reservoir for the storage of water, inasmuch as the neglect of this precaution encourages these diatom growths.

Mr. Whipple reaches the following conclusions:

(1) That the growth of diatoms in ponds is directly connected with the phenomenon of stagnation; that their development does not occur when the lower strata of water are quiescent, on account of greater density, but rather during those periods of the year when the water is in circulation from top to bottom.

(2) That diatoms flourish best in ponds having muddy bottoms.

(3) That in deep ponds there are two well-defined periods of growth—one in the spring and one in the fall; that in shallow ponds there is usually a spring growth but no regular fall growth, and that other growths may occur at irregular intervals as the wind happens to stir up the water.

(4) That the two most important conditions for the growth of diatoms are a sufficient supply of nitrates and a free circulation of air, and that both these conditions are found at those periods of the year when the water is in circulation.

(5) That while temperature has possibly a slight influence on the growth of diatoms, it is of so little importance that it does not affect their seasonal distribution.

(6) That the increase of diatoms takes place substantially in accordance with the law of geometrical progression, and that the cessation of their growth is caused by the diminution of their food supply.

The Mechanical Engineers' Pocket-Book.—A reference book of rules, tables, data and formulæ, for the use of engineers, mechanics and students. By William Kent, A.M., M.E. First thousand, first edition. New York: John Wiley & Sons, 1895. 1087 pages, 4x6½ inches, including index. Price, $5.00.

To attempt anything like an adequate review of this admirable work would be idle; first, because it would occupy an entire number of the JOURNAL, and second, because no engineer, mechanical, civil, mining, electrical, hydraulic or marine, can afford to be without a copy, and hence an extended review is uncalled for.

Suffice it to say here that every page gives evidence of conscientious pains-taking on the part of the author, who, while he has freely (and most properly) availed himself of results published by others, has done so without falling into those scissors-and-paste methods which have made the average pocket-book the useless article it is.

The publishers seem to have vied with the author in making this book what it ought to be, and the result is a thoroughly presentable, readable and indispensable addition to the Engineers' Library.

Portland Cement. A monograph. By Charles D. Jameson, Professor of Engineering, State University of Iowa, Iowa City, Iowa, 1895. *The Transit*, Vol. III, No. 1, January 1895.

An entire number of *The Transit*, containing 192 pages, is devoted to this valuable treatise on Portland Cement. The author has already commended himself to public favor by a series of admirably written papers on Railroad Surveying, and the care and thoroughness bestowed upon their preparation has evidently not been witheld in the writing of the present paper.

The author covers the entire ground of his subject, embracing the natural materials entering into the composition of cement, their preparation, the history of the manufacture and use of cement, cement specifications and tests, the chemistry of the hardening of cements, and the use of cements in actual construction.

Typographically the work is well presented, and it is thoroughly and admirably illustrated. The illustrations include a number of fine photographic views showing the use of concrete on the Hennepin Canal and at the Leland Stanford, Jr., University.

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THE CHICAGO SANITARY DISTRICT CANAL.

IV. Description of the Work and Methods of Construction on the Summit Division.

BY E. R. SHNABLE, MEMBER OF THE WESTERN SOCIETY OF ENGINEERS.

[Read, February 6, 1895.*]

INTRODUCTORY.

ALTHOUGH the force on each section is carefully taken twice a day, a discussion of the cost of the various methods employed on the Summit Division must necessarily be omitted at this time. This subject cannot be taken up, properly, until after the completion of the canal. I will, therefore, ask the Society's indulgence while describing briefly other matters of less interest.

LOCATION.

The Summit Division comprises sections "C," "D," "E," "F," "G" and "H." The first three being west of the Summit—Riverside Road—and the last three being east thereof. Section "F" occupies the lowest divide between the Mississippi Valley and the Basin of the Great Lakes. Before the river diversion levees were constructed, I have seen the spring freshets of the Des Plaines River and the melting snow and ice on this section flow westerly over the Summit Road and

* Manuscript received May 3, 1895.—*Secretary, Ass'n of Eng. Socs.*

easterly into the Ogden Ditch, which empties into the Chicago River. The tangents of the main channel were located nearly parallel to the old Illinois and Michigan Canal, the 3-degree curve of this canal being replaced by a 30-minute curve of the new canal. This curve is 6,510 feet long and lies across the east half of Section "E," across Section "F," extending 100 feet into Section "G." The center of the curve was located from the point of intersection. The initial point of the location being at the Willow Springs Road the curve was turned from the P. T. It was measured over levees, private railroad tracks, a highway embankment, through ice loading platforms, willow brush and weeds, with water standing two feet deep in places, and checked on the center of curve and P. C. to one-tenth of a foot for distance and the width of a flag-pole for alignment.

CROSS-SECTION.

The cross-sections are from 31 to 40 feet deep, 202 feet wide at the bottom, with 2 to 1 slopes, 27½ feet above grade, above which point the slopes change to 1½ to 1. This channel, of 600,000 cubic feet per minute capacity, is being constructed from Willow Springs to the Summit Road, where it contracts to the half-channel and thus continues to Robey Street in Chicago. The half-channel is 110 feet wide at the bottom, with 2 to 1 slopes to the surface.

MATERIAL.

The material, excavated and to be excavated, is composed of loam, decomposed vegetable deposits, sand, gravel, clays, hardpan and solid rock. The quantities in each section are approximate, until such time as the surface of the solid rock is completely uncovered. The total quantities to be excavated in each section, based upon the incomplete data now at hand, are as follows:

Section.	Glacial Drift.	Solid Rock.
C	1,887,755 c. y.	
D	1,877,721 "	137,694 c. y.
E	1,813,659 "	78,765 "
F	1,093,653 "	16,724 "
G	1,364,075 "	
H	1,077,032 "	
Totals,	9,113,895 c. y.	233,180 c. y.

These quantities, with 429,850 cubic yards in the River Diversion and Levees and a few collateral items, make the cost of the Division

$2,772,909. Up to January 1, 1895, $1,015,952.99 have been estimated, and, excepting the 12½ percentage retained, have been vouchered in semi-monthly payments.

SECTION "C," WESTERN DREDGING AND IMPROVEMENT CO.

The lower half of this section occupies the former bed of the Des Plaines River. Consequently the Diversion channel was necessarily excavated first. This channel has a base of 200 feet, 1 to 1 slopes, and an average cutting of about 5 feet. This work was done during 1893, with two Barnhart steam shovels and inclines, supplemented with a large wheelscraper force.

At the same time a large wheelscraper force excavated the first 8 feet of the east and dry half of the main channel. During November, 1893, a steam-shovel and work-train plant was installed, consisting of 2 special Barnhart shovels, 4 locomotives and 26 flat cars with a side-plow and cable. This method of unloading flat cars with side plow was soon abandoned. Large dump-cars, after the plans of Mr. J. O. Wright, General Manager, were built in Joliet and also by the U. S. Car Company. They are 12 feet long, 11 feet 8 inches wide and 18 inches deep, inside measure, of 7⅞ cubic yards capacity, struck measure. These cars are wider than usually built, and have the advantage of clearing themselves readily in being dumped. The overlying earth and soft clays having been removed by teams, the material left for the steam shovels is found to vary in short distances. The formation is of the nature of hardpan and boulder hummocks or waves with pockets or hollows of sand and sandy clay. The two shovels, progressing longitudinally, may have 50 feet of free digging, while the next 100 feet of progress may require drilling and blasting.

The output per working day consequently varies. For July the average output per working day per shovel was 762 cubic yards; in August, 533 cubic yards; in September, 820 cubic yards; in October, 493; in November, 503, and in December, 538.

The daily force is distributed as follows:

OUTPUT AND DISPOSITION OF MATERIAL.

2 Foremen,	2 Shovel Enginemen,
2 Cranesmen,	2 Firemen,
8 Pitmen,	4 Locomotive Enginemen,
4 Trainmen,	18 to 26 Dumpmen.
3 to 12 Ditchers,	

REPAIRS OF PLANT.

1 Foreman,	12 Track laborers,
1 Machinist,	1 Blacksmith,
1 Blacksmith Helper,	2 Car Repairers.

DRILLING AND BLASTING.

3 Laborers.

PIT PUMPING.

2 Pumpmen.

FEED WATER SUPPLY.

1 Pumpman.

GENERAL EXPENSES.

1 Superintendent, 1 Watchman,
1 Timekeeper, 1 Electrician,
1 Swing Team.

Night work was abandoned on December 8th, on account of the cold weather. The plant consists of 2 steam-shovels, 4 locomotives, 32 dump-cars, 3 centrifugal pumps, 1 dynamo and 2½ miles of standard gauge track. The first view, Fig. 1, is taken at about the middle of the section looking east.

SECTION "D."—E. D. SMITH & CO., CONTRACTORS.

The material in this section is similar to that of Section "C." The Des Plaines River, not interfering with the main channel and spoil bank as located, was not diverted. In April, 1893, the contractors began work by first putting up a temporary levee with a wheelbarrow force. Upon this embankment a standard gauge-track was laid, connecting their work with the Chicago and Calumet Terminal Railway. The next view, Fig. 2, is a map of this section showing the plan adopted by the contractors, and the gradual shifting of the tracks as the work progressed. It may be called a double " Y " stub-end method. The shovels were started at the center of the section, one headed east and the other west. When the work was started the tracks lay as shown and marked " AA." After each cut, as shown by the specimen cross-section on the left of the map (which is one of the monthly progress record), the pit-tracks are shifted, the incline-track correspondingly lengthened until they now occupy the position marked "BB." The unloading tracks were located as shown at "AA," and have gradually been moved to the position marked "BB," as the spoil-bank increased in width. 14° or 16° curves were adopted. The map also shows the various camp, store and shop-buildings in use. Two Worthington duplex pumps are located in the pit near the middle of the section. One is in constant service, while the other is held in reserve for emergencies, such as a heavy rainfall, or while the other pump is being shifted or repaired.

The waste-water is discharged into the Illinois and Michigan Canal through a ditch and box culvert. During the past year progress was materially aided by a large New Era grader and wheelscraper force; 352,430 cubic yards being removed by this method, "C."

Fig. 1.

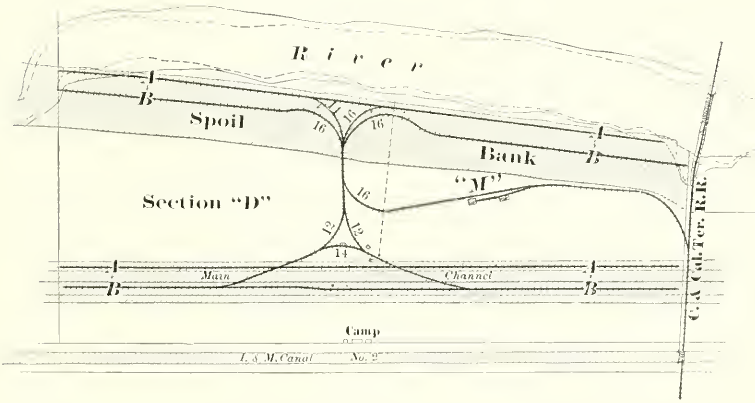
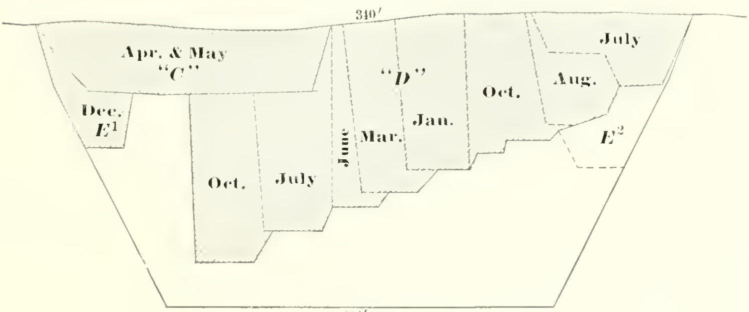


Fig. 2.



Specimen Cross-Section.

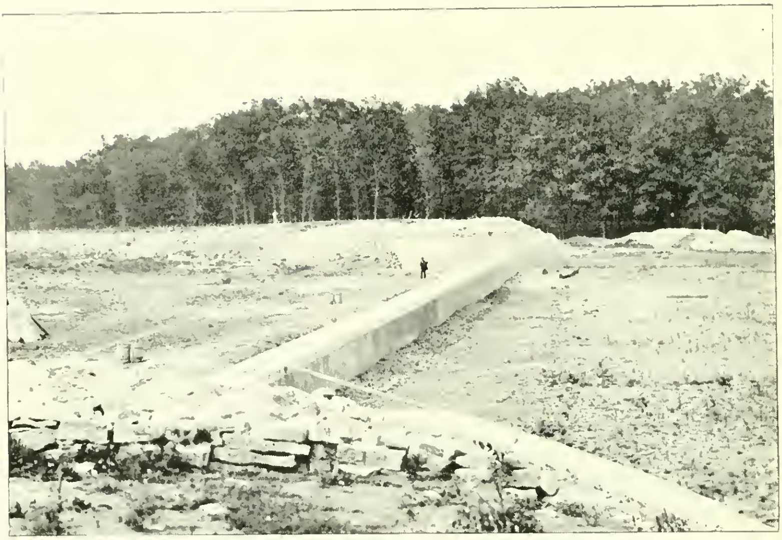


FIG. 3.

For Fig. 4, see folded insert sheet.

FIG. 5.

To insure the early completion of this section, a third steam-shovel was purchased. By referring to the specimen cross-section it will be seen that a large quantity of material will be left lying on the left-hand slope, "E," which the lower shovels cannot reach. The third shovel is now working down this slope, the material being loaded into 3-horse wagons. When this work is completed the shovel will be transferred to the right slope, "E_2," and will work down this slope in a similar manner. When the pit-shovels reach the foot of the left slope, at grade "D," they will begin excavating towards the right, on the plane of this grade. The method of working this section has been well planned, and is being managed with commendable executive ability. The entire plant was new when installed, and no changes of plan nor plant have been made since the work began. The plant consists of 1 "A" frame and 2 special Bucyrus steam-shovels, 4 Baldwin saddle-tank locomotives, $3\frac{1}{2}$ miles of standard gauge track, and 40 Corey dump-cars. These cars are 9 feet 6 inches long, 8 feet wide and 2 feet deep, holding $5\frac{6}{10}$ cubic yards, struck measure. The daily average output per shovel has varied from 800 to 1,200 cubic yards per working day. Up to February 1st, 1,147,-731 cubic yards have been removed.

SECTION "E."—STREETER AND KENEFICK, CONTRACTORS.

The material in the west half of this section is similar to that of sections "C" and "D," lacking, however, its sandy and friable character. In the east half we find loam, clay, a homogeneous or cemented hardpan, cheesy clay, bull liver, boulders, and solid limestone, in the order named. The hardpan or boulder clay is too hard to excavate without the use of powder. Drilling is costly, as the imbedded gravel and small boulders bind the drill bar. This hardpan does not soften in the least under water, when first taken out of the pit. After a piece has been exposed to the air until dry it dissolves rapidly upon immersion. Bull liver, so called by well diggers, is a mixture of very fine sand, pulverized limestone, and water. It is water-bearing, but not porous, as hard to dig as clay when in place, and when stirred up as sticky as molasses and more treacherous than quicksand. As yet it has not been uncovered by the contractors, but was encountered in sinking test pits. Approximately there are 336,900 cubic yards of this material on this section.

During the season of 1893 the contractors removed the upper 3 to 8 feet (about 469,000 cubic yards) with a large wheelscraper force. The section was divided into five parts and the work was done by five outfits.

One of my assistants, Mr. J. H. Brace, tabulated the following information, showing a comparison, due to the nature of the material and management.

STATIONS. From	STATIONS. To	Average Fill.	Average Cut.	Total Lift.	Average Haul.	Total Excavation.	Method of Excavation.
		Feet.	*Feet.*	*Feet.*	*Feet.*	*Cubic Yards.*	
460	470	12.0	8.0	20.0	400	94,879	Wheelscrapers.
470	480	12.0	8.3	20.3	400	98,515	"
480	490	11.0	7.0	18.0	400	85,761	"
490	500	7.0	3.4	10.4	400	33,185	"
500	507	7.0	4.3	11.3	400	29,678	"

STATIONS.		Daily Averages, Cu. Yds. Excavated.		Ratio of Teams.		REMARKS.
From	To	Per Team.	Per Wheel-scraper.	Wheel-scraper to Plow Team.	Wheel-scraper to Snatch Team.	Nature of Material.
460	470	29.8	42.2	$5\frac{1}{3}$ -1	$4\frac{1}{10}$ -1	Very stiff blue and yellow clay, with a few large boulders.
470	480	27.1	39.3	$4\frac{9}{10}$ -1	$4\frac{1}{10}$ -1	
480	490	24.4	35.2	$4\frac{8}{10}$ -1	$4\frac{3}{10}$ -1	
490	500	35.0	50.1	$4\frac{9}{10}$ -1	$4\frac{4}{10}$ -1	Stiff, yellow clay, containing a great number of boulders of all sizes.
500	507	28.3	42.1	$4\frac{6}{10}$ -1	$3\frac{7}{10}$ -1	

During August, 1893, a steam-shovel plant was installed, consisting of two Bucyrus shovels, four small locomotives, and fifty small, narrow-gauge dump cars. After a month's work the contractors were compelled to use powder, as the shovels were unable to dig the hardpan in paying quantities. January 15, 1894, this work was shut down, the contractors petitioning for relief. August 29th a re-letting was ordered. On September 19th, Angus and Gindele were awarded the contract. These contractors have adopted the steam-shovel and work train method, with standard-gauge track on the loop plan.

SECTION "F."—RICKER, LEE & CO., CONTRACTORS.

This section was more or less under water until July 15, 1893. Before that time the team forces were employed on the River diversion channel and levees. To guard against the destruction of the levees by an unheard of flood, a concrete masonry spillway, costing $20,518, was constructed in November and December. The top of the levee has an elevation of 25 feet above Chicago datum, while the top of the

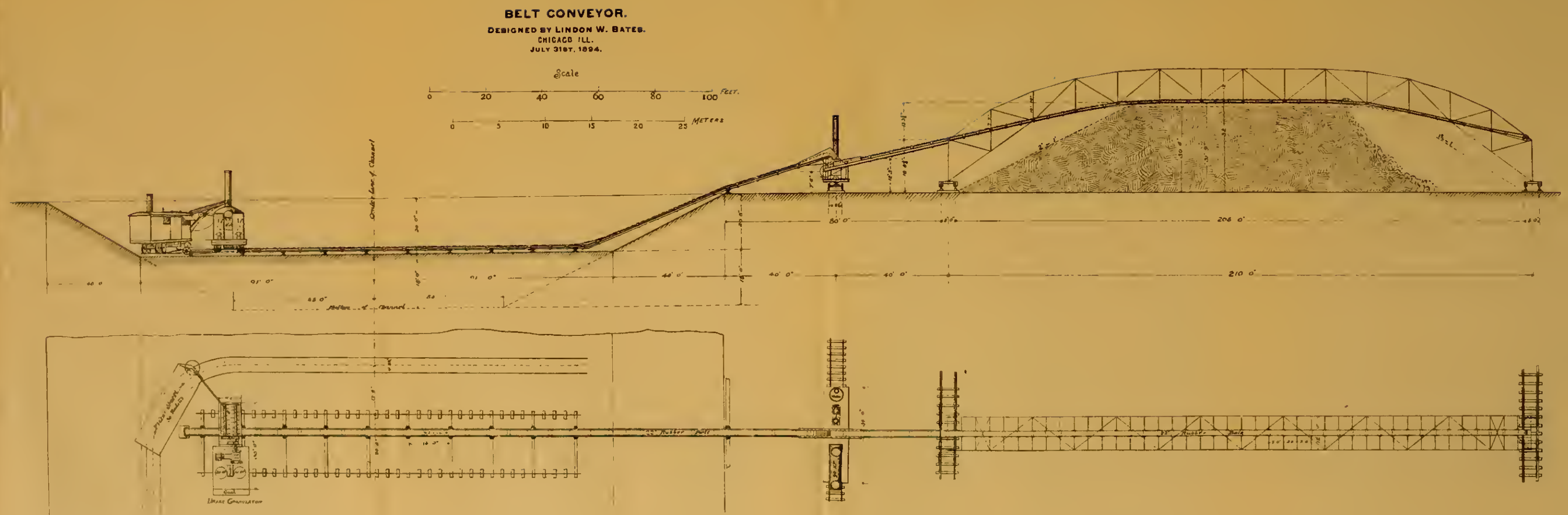

BELT CONVEYOR.
DESIGNED BY LINDON W. BATES.
CHICAGO ILL.
JULY 31ST, 1894.
Scale
0 20 40 60 80 100 FEET.
0 5 10 15 20 25 METERS
80' 0"
208' 0"
91' 0"
44' 0"
40' 0"
40' 0"
210' 0"

Fig 4.

spillway is 16.25 feet above datum. This spillway is now the lowest divide between the Mississippi Valley and the Basin of the Great Lakes. The flood-waters of the Des Plaines River poured over this spillway last March for but a short period of 61 hours. After provisions have been made for carrying the combined waters of the Drainage Canal and Des Plaines River through Joliet, the height of the spillway will be raised sufficiently to prevent any of the flood-waters from reaching the Chicago River. The next view, Fig. 3, shows this spillway, looking north.

The material of this section consists of loam, soft clay (with beds of sand in which were found trunks and branches of trees, small shells and black walnuts), boulder clay or hardpan, cheesy clay, bull liver, boulders and solid lime stone, in the order named. Two steam-shovels and a large team force were employed at the same time. The section being in water-bearing strata, the shovels were worked on a lower plane, thus permitting the working of teams. The material was thus removed down to the boulder clay. The contractors then made another start, with steam shovels alone, employing a force of drillers and blasters.

To show the difference in material, I will add the force account and the corresponding output for a month's work in the upper clay and the same for a month's work in boulder clay.

IN CLAY.

The daily force is distributed as follows:

OUTPUT AND DISPOSITION OF MATERIAL.

2 Foremen,	4 Locomotive Firemen,
2 Shovel Enginemen,	5 Trainmen,
2 Cranesmen,	25 Dumpmen,
2 Firemen,	2 Ditchers,
12 Pitmen,	2 Waterboys.
4 Locomotive Enginemen,	

REPAIRS OF PLANT.

1 Foreman,	1 Car Repairer,
10 Trackmen,	1 Blacksmith,
1 Machinist,	1 Blacksmith Helper.

PIT PUMPING.

2 Pumpmen.

FEEDWATER SUPPLY.

1 Pumpman.

GENERAL EXPENSES.

1 Superintendent,	5 Watchmen,
1 Timekeeper.	

PLANT EMPLOYED.

2 Bucyrus Steam Shovels,
30 Thatcher Dump Carts,
3 Pumps.

The daily average output per shovel for the month was 732 cubic yards.

IN HARDPAN OR BOULDER CLAY.

OUTPUT AND DISPOSITION OF MATERIAL.

2 Foremen,
2 Shovel Enginemen,
2 Cranesmen,
2 Firemen,
12 Pitmen,
3 Locomotive Enginemen,
3 Locomotive Firemen,
2 Trainmen,
12 Dumpmen,
2 Ditchers,
2 Waterboys.

REPAIRS OF PLANT.

1 Foreman,
10 Trackmen,
1 Machinist,
1 Car Repairer,
1 Blacksmith,
1 Blacksmith Helper.

PIT PUMPING.

2 Pumpmen.

FEEDWATER SUPPLY.

1 Pumpman.

DRILLING AND BLASTING.

16 Laborers,
1 Foreman.

GENERAL EXPENSES.

1 Superintendent,
1 Timekeeper,
4 Watchmen.

PLANT EMPLOYED.

2 Bucyrus Shovels,
24 Thatcher Dump Cars,
3 Pumps.

The daily average output per shovel for this month was but 440 cubic yards.

The contractors then gave up this section and the work has been recently awarded to F. C. Weir of Cincinnati.

The plant now stored on this section by Ricker, Lee & Co., consists of one "A" frame and two Bucyrus steam shovels, one Otis steam-shovel, four large locomotives, three miles of standard-gauge track and thirty Thatcher air dump cars. These cars are 11 feet 9 inches long, 8 feet 3 inches wide and 2 feet 6 inches deep, holding 9 cubic yards, struck measure. They weigh about 17,600 pounds and are designed for a 40,000 pounds capacity.

SECTION "G."—GAHAN & BYRNE, CONTRACTORS.

The material in this section consists of loam, soft and hard clay and some hardpan in the west third. A wheelscraper force removed

Figs. 6 and 7 omitted.

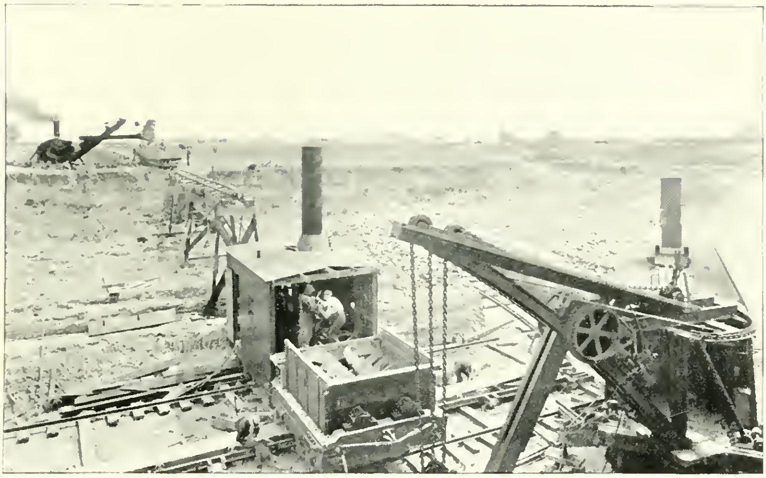


FIG. 8.

FIG. 9.

GENERAL FORCE.

1 Coal-passer,	1 Coal-cart and Driver.

To remove the lower lift, a steam-shovel and incline plant is now being installed. This plant will follow the Belt. The next view, Fig. 11, shown, is a general plan of this method. The shovel works crosswise and loads the alternating cars carried by the incline. This method and incline were designed by Mr. J. W. Page, the contractor's engineer. A few of the advantages of this method may be mentioned. As the incline travels the full length of the section but once, only two miles of track-laying is necessary. The engine-man, being placed in the power-car ahead of the incline, and near the top of the slope, is enabled to see the cars in the pit and on the tipple. The next view, Fig. 12, shows the detailed plan of the incline. This structure weighs 54,000 pounds. The car, when loaded, weighs 15,000 pounds. The strains were carefully computed and checked. A new feature is the double, large and small counter-balance for the tipple. This arrangement insures rapid tipping, without heavy shocks.

SECTION "H."—GAHAN & BYRNE, CONTRACTORS.

The material in this section is similar to that in section "G," with less hardpan. A large wheelscraper force removed the upper four feet during 1894. During last November a Barnhart steam-shovel, loading Peteler cars, drawn by horses, was installed in the triangular west end of the section. Where the full width of Sanitary District's right of way is not interfered with by that of the Santa Fé Railway, a pit was excavated by wheelscrapers, during July, for the Hoover-Mason conveyor. The strike of last summer seriously retarded the delivery of material for this machine. However, by September 25th, this machine began removing material, using one plow and thirty-four shovelers. The wheelscraper pit was 11 feet deep, and this method was adopted in lowering the pit to grade. By October 15th the conveyor pans and carrying track were extended and lowered to the bottom of this pit. Some time was then consumed in properly shaping the pit and adjusting the manner of hitching the plowline to the plow in its various vertical positions. The next view, Fig. 13, illustrates the general plan. It represents the size of the structure and the manner of supporting the track, which carries the continuous steel pan conveyor over 1300 feet in length. The pans are 4 x 4 feet, hinged on 2-inch axles with 12-inch wheels. The ends of the axles have ¼-inch holes filled with dope, under the pressure of brass coil springs. This makes the conveyor self-lubricating for a period of one week. The axles are connected by two eye-bars, tested to stand a strain of 40,000 pounds. The speed of the conveyor is

INCLINE AND TIPPLE
FOR
SEC. "G" DRAINAGE CANAL
CAHAN AND BYRNE CONTRACTORS.

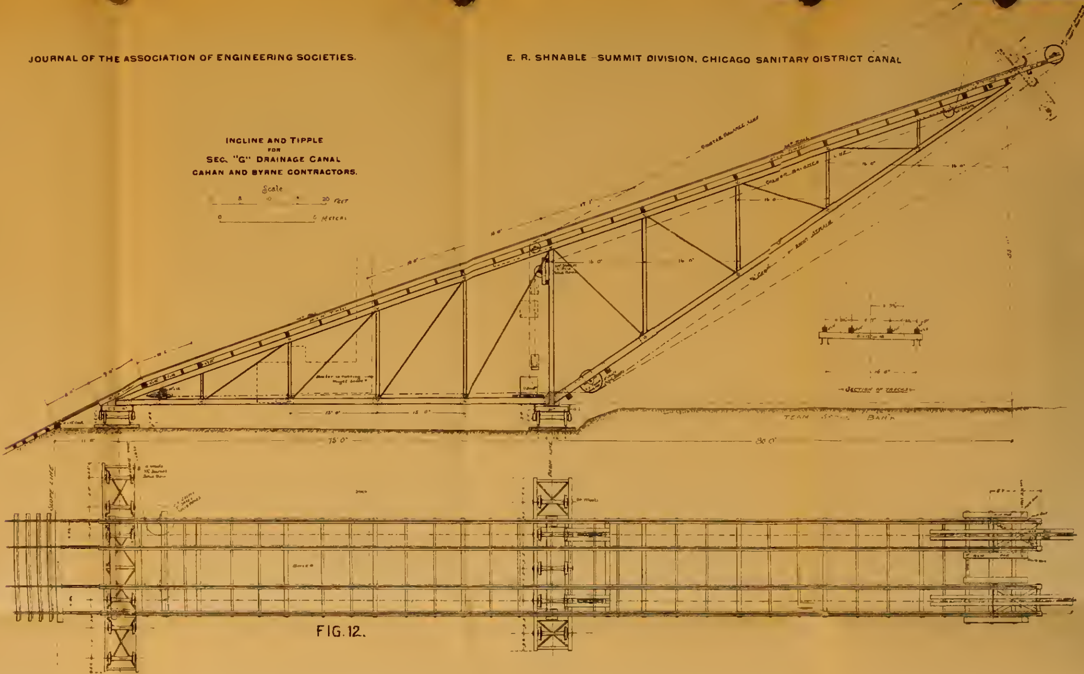


FIG. 12.

INCLINE AND TIPPLE
FOR
SEC. "G" DRAINAGE CANAL
CAHAN AND BYRNE CONTRACTORS
DESIGNED BY J. W. PAGE.

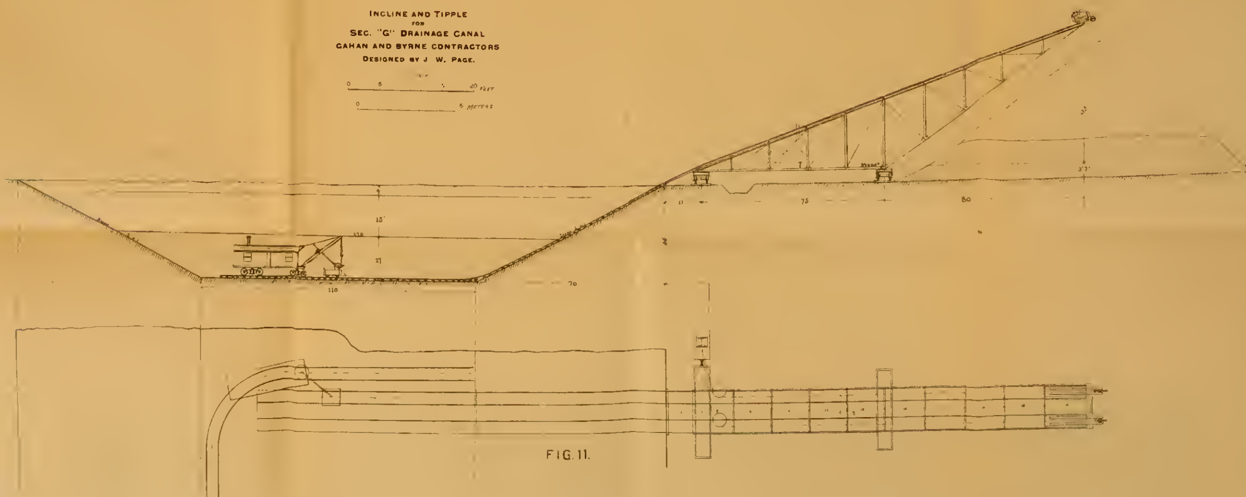


FIG. 11.

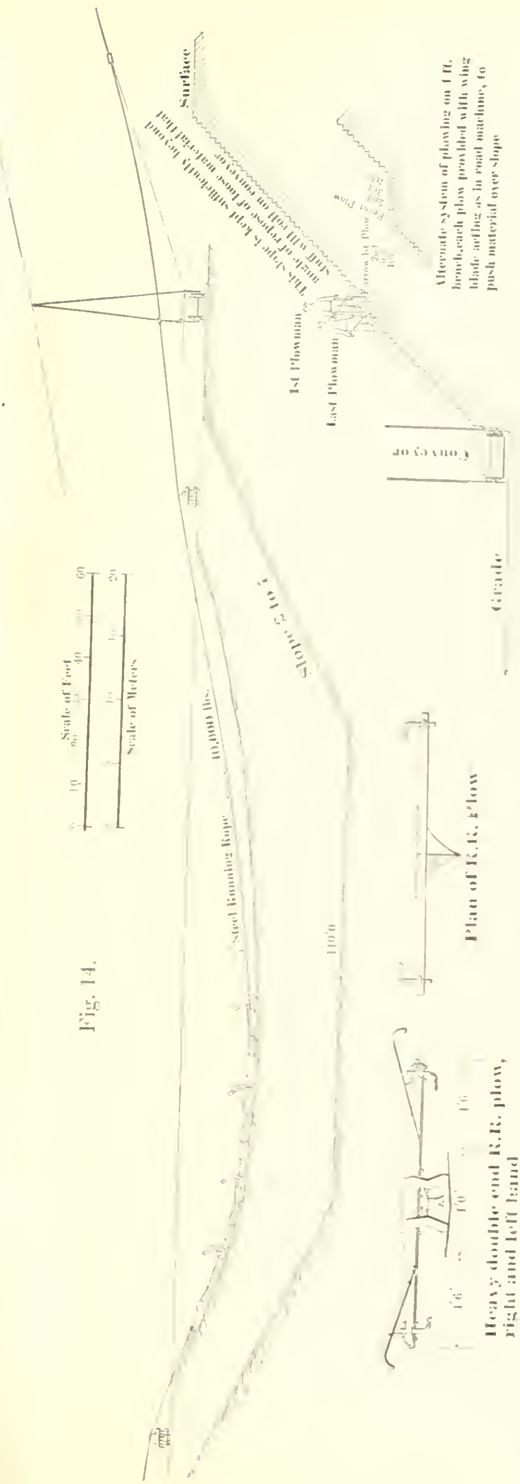

Surface
This slope is kept sufficiently beyond angle of repose of loose material that slag will roll on conveyor
1st Plowman
Last Plowman
Alternate system of plowing on 1 ft. bench, each plow provided with wing blade acting as in road machine, to push material over slope
Conveyor
Grade
Slope 3 to 1
10,000 lbs.
Steel Running Rope
Scale of Feet
Scale of Meters
Plan of R.R. Plow
Heavy double end R.R. plow, right and left hand

Fig. 14.

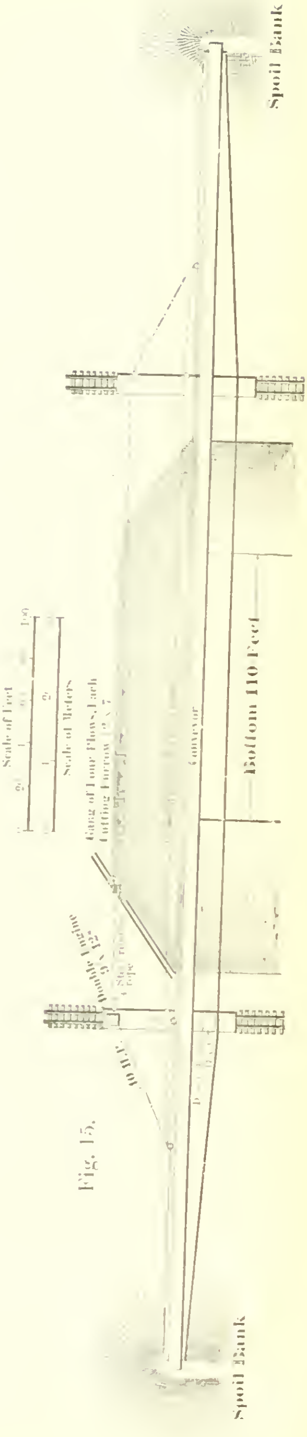

Spoil Bank
Bottom 110 Feet
Conveyor
Scale of Feet
Scale of Meters
Double Engine
Spoil Bank

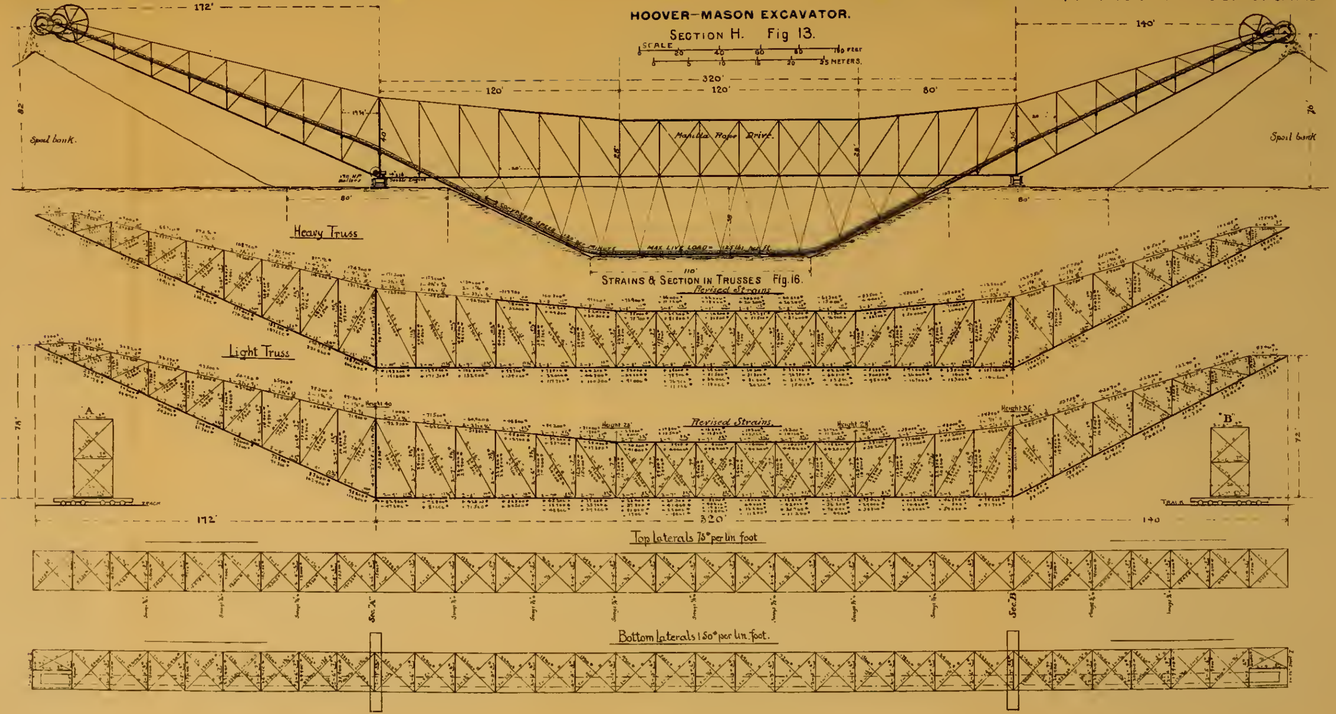
Fig. 15.

120 feet per minute, and weighs 125 pounds per linear foot. The power, from a double 14 x 17 inch engine, is transmitted by a double manilla rope drive to the gearing at the ends. Two boilers, of 150 horse-power capacity, carried on a separate car, supply the steam for the plow and conveyor engines. This part of the machine operated with remarkable smoothness, due to the perfect design and construction of its parts. However, an unfortunate accident occurred November 8th. The cross timbers, which support the track and conveyor, were rip-sawed to allow the diagonal wind braces to pass by them. The timber over the car carrying the long arm was found to be defective. Until it could be replaced a jack was put under the middle of it. While moving up the machine the jack became loosened and fell. The pans, being loaded heavily at the time, suddenly broke this timber in two.

The sagging conveyor and its load, the span being doubled, broke the next timber. This performance was repeated and the next timber was broken. In the meantime, the wind braces were carried away, and when the falling conveyor struck the lower struts, the stability of the truss was destroyed. The north arm then collapsed. Arrangements were immediately made to repair the damage. Just as the repairs had been made the seventy-mile-an hour hurricane of January 21st came, striking the machine broadsides. Although the car wheels were blocked with 4-inch chocks, the machine started to move before the foreman in charge realized the violence of the gale. As the machine stood over a pit with its almost vertical face against the wind, a sufficient upward pressure must have been exerted to reduce the holding friction of the blocking.

The machine ran off of its tracks, the heavy steel cars were buried in the ground, tripping the points of support and thus toppling over the whole structure. The main truss landed on its side, sustaining very little damage, while the two arms were hopelessly wrecked. The machine is to be rebuilt with but one arm, and will take out the lower half of the section. While being rebuilt, an incline similar to the one described on Section "G" will remove the upper half. This, popularly-called "cantilever conveyor," attracted unusual attention, owing to the boldness and magnitude of design. This, with the careful working out of original ideas, the exceptional ability displayed in its construction, make the accidents, occurring before the economic efficiency could be determined, more than unfortunate. Messrs. Gahan and Byrne fully deserve the high esteem of the engineering profession, by risking their time, money, and reputation, while encouraging such efforts of its members. The next view, Fig. 14, shows a cross-section of the pit and the manner of loading the conveyor with plows. It also shows an elevation and plan of the double-ended plow used. The use of four small plows was first contemplated, but up to the time of the accident, only

HOOVER–MASON EXCAVATOR.



For Fig. 16, see folded insert sheet.

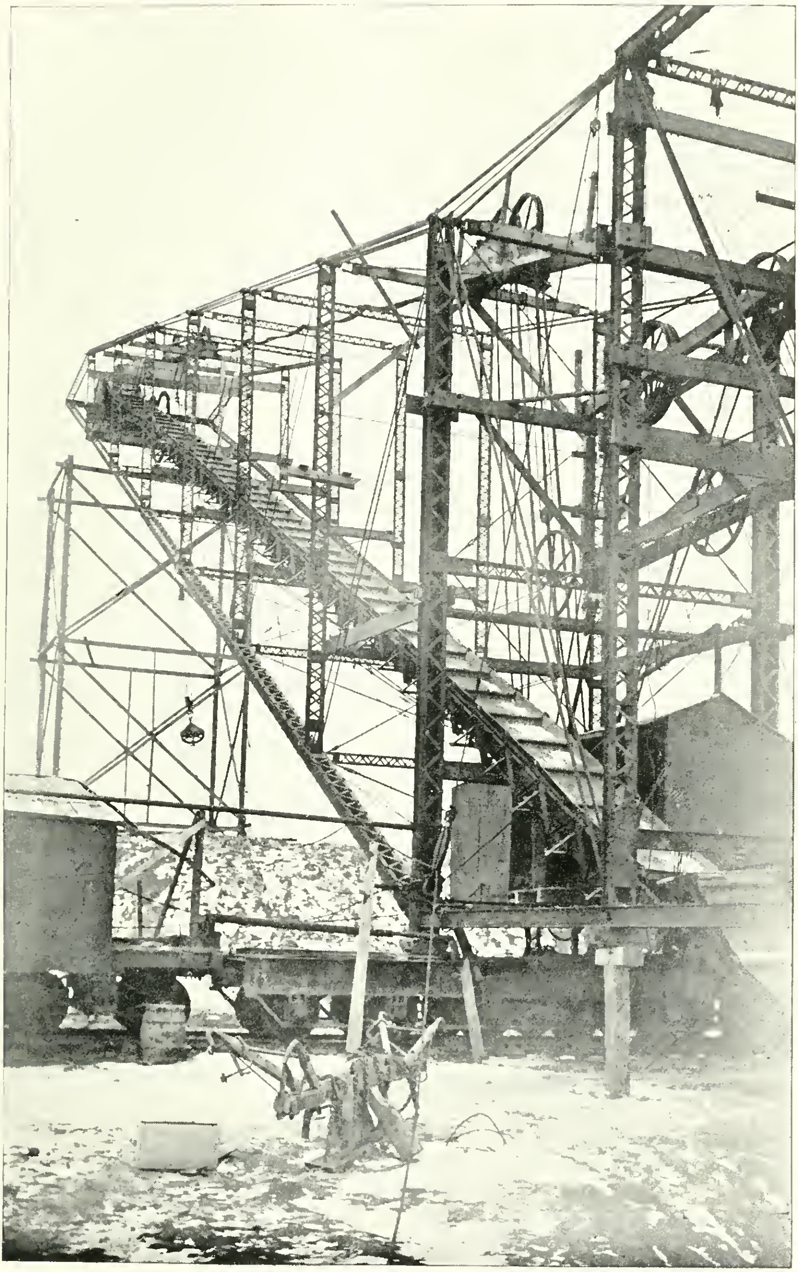


FIG. 17.

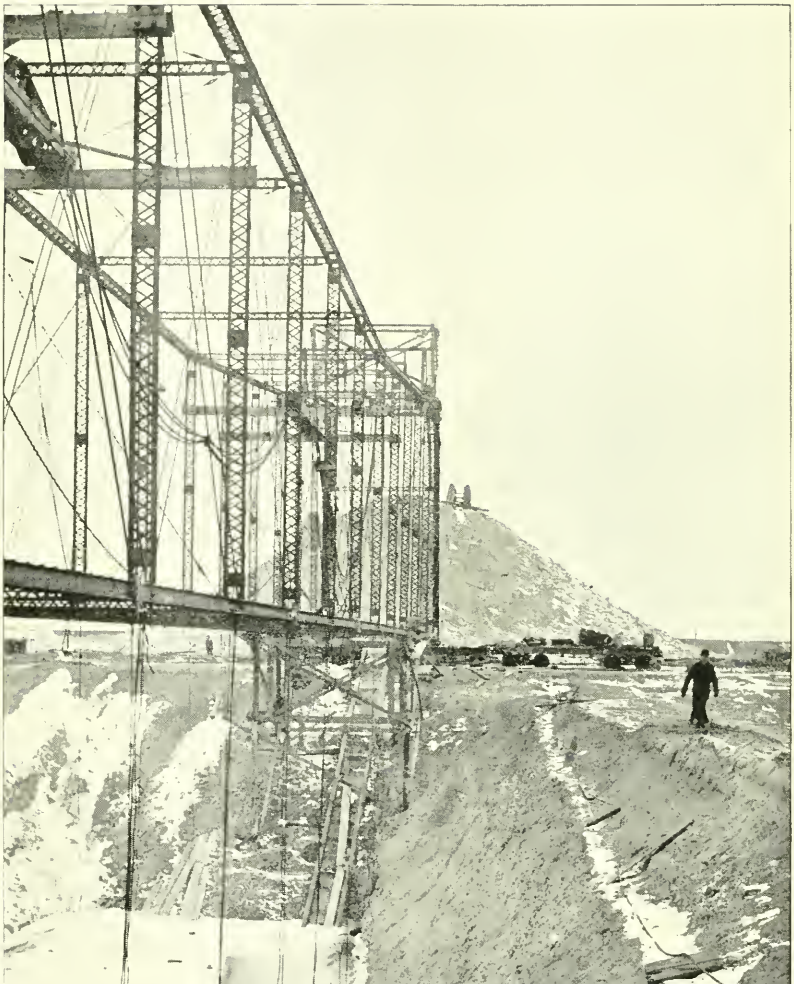


Fig. 18.

one was operated. This plow cuts a furrow 7 inches by 20 inches and 200 feet long in one minute, or 4,321 cubic yards in ten hours. Allowing for reversals, changing of hitch and minor delays, the efficiency of one plow can be safely assumed to be 3,000 cubic yards per day. The power from a 10 x 12-inch engine, applied to the plow line is 10,000 pounds. As the plow works down the face of the pit, the pulling line is gradually moved parallel to itself and toward the conveyor. The plow line closely approaches a catenary curve, and the sheaves, through which it runs, are lowered as the plow descends. The points of the plow are slightly turned both downward and towards the face of the cut, giving a bite in two directions. The four adjustable shoes, shown in plans, counteract this tendency sufficiently to keep the plow steady. The hitch on the plow beam is adjustable, and is made by a half-hitch in a chain. This movable hitch is necessary owing to the change of direction of the pull. The next view, Fig. 15, is a plan of the pit and shows the movement of the plow line and sheaves. The next view, Fig. 16, shows the strain sheets. The next two views, photos Figs. 17 and 18, show the conveyor as built.

CONCLUSION.

In conclusion allow me to thank Professors Hatch, Stine, and Snow, representing the Armour Institute, for their generous kindness in preparing the numerous slides, exhibited to-night by means of an electric lantern, especially installed for this occasion.

SHOULD OUR PATENT LAWS BE ABOLISHED OR MODIFIED?

By John Richards, Member of the Technical Society of the Pacific Coast.

[Read July 6, 1894.*]

The problem of personal property in inventions, which is in a sense included in the question presented for this evening, has been the subject of profound investigation for more than a century past, and the rightfulness of such property has been defended by statesmen and jurists of all countries, so that a discussion of the expediency of abolishing the Patent Laws is not likely to do much good, but rather to be a waste of time and effort.

Patent laws exist in all civilized countries, Holland excepted, and countries that have abrogated their patent laws have again instituted them. Among these is Switzerland, where we have reason to believe that legislation and national economy have their highest development at this day. Besides, the tendencies of our time do not point in the direction of restricting monopoly, but, on the contrary, to its extension in various forms. This is true of nearly all civilized countries, and especially of the United States, where not only the powers of legislation but their construction is warped to promote private interests in a greater degree than at any previous time. Competition and free commerce are hampered in a hundred ways, and among all the privileges permitted or promoted by law, none are so harmless, or have so much to claim in the way of equity, as the questionable monopoly permitted to inventors who obtain patents.

In the case of most of the patents granted on mechanical inventions the object is to prevent imitation and protect manufacturers, and the amount added to the selling price of commodities by reason of such patents is commonly very little and sometimes nothing, but there are other privileges, granted without the qualifying conditions that attach to patents on inventions, that raise the price of commodities in some cases a hundred per cent., and in many cases fifty per cent., such grants or privileges being absolute, and not even binding the beneficiary to turn over to the public at the end of seventeen years a consideration presumably equal to the privilege received.

The natural right of a person to exclusive use of what he may have

* Copy received April 25, 1895.—*Secretary, Ass'n of Eng. Socs.*

discovered or invented, or, in legal terms, the property in invention, cannot be questioned upon any other grounds than the abridgment of some right of other persons or of the public, and such abridgment could be proven only by one of two facts: that the invention or discovery was not new and original, and that the public could by other means have acquired the same advantage sooner and on better terms.

A patent is in its nature a contract between an inventor and the public, in which it is stipulated that if the patentee will file in the archives of the Government a complete description of his invention with drawings that will enable others to understand, make and use his invention at the end of seventeen years, he shall for that length of time enjoy a monopoly and exclusive use of his discovery.

This grant is not absolute, but is conditional on the invention being new, and that it does not interfere with rights and privileges already existing. It is also qualified by other conditions, such as the perspicuity of the description and its completeness, also the language employed in defining the scope of the patent, so that, on the whole, letters patent in this country seem in comparison a tame kind of monopoly, and indeed is only a reasonable bargain with the principal stipulations against the patentee, who must maintain at his own expense, and risk all the conditions imposed upon him by the grant.

These remarks upon the nature of patents for inventions are necessary in order to properly consider the practical working and the abuses of our patent system, to which the question of this evening seems to be directed.

The extent of the influence of patents on our industrial interests in this country is not known, or suspected even, nor is the methods of that influence very well understood. There are very few manufactures started at this day that are not founded on some kind of protection. This may be by large aggregations of capital, and an organization that permits cheap production; by combinations of a number of manufacturers to control prices; by secret processes and special skill acquired throughout generations, and by patented rights that secure to the manufacturer the exclusive use of certain implements, processes or products; also by a combination of two or more of these means, often all of them, in the case of extensive manufactures. Among these means of founding and protecting manufactures only two are open to a poor man, or a small manufacturer, the secrecy of processes and patents, as before said, and in these rest the greater share of new ventures in the skilled industry of our country.

It seems a strange proposition to oppose monopoly with monopoly, but in this case it is done. It is almost the only means left to a people struggling against vast aggregations of capital and resources that are dragging us each year nearer to socialism.

If, in this city, one of our large iron works had free use and contro- of all the inventions in that branch of mechanic art, there would soon be but that one works here, and the owners would paternally care for all the people employed or connected with that industry. It would be the same thing if extended to other interests, and the division of industry would cease in the various branches now carried on. Opposed to this concentration is our patent system. It stands almost alone, but its power is great, and with intelligent and honest administration of our laws it insures in some degree a division of our manufactures, and permits people without large capital to carry on business. Whether it is desirable to narrow individual enterprise, and concentrate our industries in large combinations, is another phase of the subject that cannot be discussed here.

The agency of patented inventions in developing and improving processes and products is the argument commonly set forth in support of a patent system. Whatever this influence may be it is of less importance than the one just mentioned. The "nature" of what we call progress at this day is much less important than the "manner" of it and the social effects resulting therefrom, hence this point may also be passed over here.

Reverting now to the modification of our patent laws, there are several serious impediments to reform. There is first the difficulty of securing the required attention and service in Congress to this or any other matter of national concern. There is no one to promote new measures of the kind. The country at large has no Representatives or Senators in Congress. These all represent the interests of their especial districts, states and constituents, also themselves, and there is no direct incentive to inspire legislative effort on behalf of Federal laws of general and equal application.

The Patent Bureau at this time has not more than one-half the office room required, but has a credit of between three and four millions of dollars in the patent fund, a surplus of fees paid in by inventors, and so long as a requirement so obvious cannot engage the attention of Congress there is little hope of amendment of the patent laws. Other kinds of grants and monopoly require all its time and energies.

Within twelve days past a duty of $2.07 per thousand has been assessed on blasting caps, a little more than the worth and price of the caps. There are two makers of such caps in this country. They have received a patent without promise of turning over their processes and inventions to the public at the end of a term, and have the farther advantage that the Government in effect collects the royalty from the miners and turns it over to these two makers of blasting caps. This is mentioned as the kind of patents that Congress is just now engaged upon.

Another impediment is the want of understanding the nature of letters patent for inventions as a part of the National economy. The subject has engaged the attention of the most eminent men in all countries where patent laws exist, and one has only to look over some legal decisions to see the great complexity of the subject. It is one that must be viewed in the concrete, and is so mixed up with industrial and commercial affairs of the country that not one congressman in fifty could vote intelligently upon a modification of the laws, much less draft and promote new measures.

Mechanics and engineers do not often go to Congress, and happily are not often concerned in what we call politics. The late President of the French Republic is almost the only engineer that has ventured into national administration. Col. Turretini, Mayor of Geneva, and the present Mayor of San Francisco, are the only others that can be called to mind, and there is little wonder at the difficulty of dealing with patent laws in the popular legislature.

These remarks indicate the temerity with which suggestions should be entered upon here, but the present remarks would be incomplete without some criticism of the existing law. Our patent system, while it has many excellent features compared with that of other countries, is anomalous in respect to what is called the examination of applications for letters patent. There is examination, as the term applies, and to this there can be no objection. On the contrary, it is a great aid to the inventor and his attorney, saving searches that would be expensive, and even impossible, with the usual resources at hand, but the functions of the examining officers do not stop with their search. They do not, as an engineer, lawyer or other professional man would do, endorse the facts and their opinion on the application, or enter these upon the record, but are obliged to exercise judicial functions, and decide the case on their own evidence; that is, "reject" the application if in their opinion the alleged invention is not new. Such a perfunctory duty must be as disagreeable to the examiners as it is illogical and unjust to an inventor, because it assumes the power of destroying a patent with no corresponding power of confirming it. This is left for the inventor to do after the patent is granted, and, no doubt, should be, but on what grounds should a primary examiner reject a patent when he has no power to confirm it?

It is placing on him perfunctory duties that implies his want of ability to arrive at and record a professional opinion; puts him in the position professionally of a routine clerk, and officially in the position of a judge.

If the examiner's views were endorsed on the record, and the applicant had the right to appeal or call for further opinions of higher officers up to the Commissioner, the procedure would be logical and just

Patents would then be issued with a full record, and at the applicant's risk, as is done in most other countries, where repeated and invalid patents are less often granted than they are here. As it is now, a patent when issued bears no record of the office procedure, but no one thinks of purchasing a patent without sending for a transcript or what is called a "copy of the file," in the case. This should be printed with the patent at its issue, so that anyone concerned in the matter would have the whole record before them.

There are many other reasons against rejections or the judicial functions of examining officers, that are engaging an increasing amount of attention in this country, and will no doubt in the end lead to some change beneficial alike to the Bureau and to inventors.

Time will not permit a notice of some other points that could be profitably presented before the Society at this meeting, and but one other will be named,—respecting trade marks. The present law on this subject seems to be founded on the assumption that a trade-mark, registered in the Patent Office, is an attribute of the goods to which it is applied, and not a personal matter relating to the firm or company that applies for registry. The applicant is called upon to define particularly the class of goods and also the articles in that class, to which the trade mark is to be applied.

As a matter of fact, obvious to any one, a trade-mark is a short way of endorsing the name of a firm or business on goods without using personal names, that may be changed, and in this sense has no particular relation to the articles on which it is marked or stamped. The purpose is to set forth that a particular person or firm produced the goods, and the laws of registry should certainly be based on that fact and not on the assumption that the trade-mark is an attribute of the goods themselves.

Having consumed the allotted time, and perhaps more than was intended, there is but one thing more to add, that is, some mention of the honest and faithful administration of the Patent Bureau. It ranks first and stands with the Coast Survey Office and Army Engineer Corps, in this respect. Thirty-five years of continuous intercourse in one way or another with the United States Patent Office has not, but in two instances, brought to knowledge the least charge of misconduct in that Bureau, and in both these cases the charges were confined to the chief officer.

Our patent system may have faults, and naturally falls under suspicion sometimes, by those not acquainted with its organization and history, but such suspicions are groundless, in so far as the long experience before named has disclosed.

It is respectfully submitted that any abrogation of the patent law is not only inexpedient but impossible. That patent grants for invention are equitable and the least harmful among many privileges conferred by

Federal laws, and that the abuse of patent privileges is less than in the case of other laws creating privilege and inequality; also that their improvement is both possible and probable when Congress can be forced to give some attention to National affairs.

DISCUSSION.

Mr. Carsow.—I would like to ask how it is that some people get information of patents in the Patent Office before those patents are granted? In Cincinnati, an association called, I think, the American Patent Association, sends out letters to different parties advising them in regard to the status of their applications.

Mr. A. B. Bowers.—I think this information can be obtained only through the attorneys employed to present the case to the Patent Office, not through the Patent Office or any one connected with it.

Q. Is an application on file open to public inspection? For instance, would an application for a patent on a Broom machine be on file under that heading?

A. Any person bringing a power-of-attorney from an inventor can examine the application. No other person can see it except the examiner.

When an application is made for a patent, the examiner immediately compares it with all of the patents issued on the same subject in the United States, Great Britain, France and Germany, and, in cases where the inventor makes broad claims, the examination extends to still other countries, and in some instances libraries are ransacked, encyclopedias, dictionaries, technical journals, common newspapers, and the practice of those engaged in the business to which the invention is most nearly allied.

Claims for patents are examined very carefully, and any claim that the examiner thinks will be rejected by the courts, if a contest should arise, is rejected in the Patent Office. If the applicant is not satisfied with the examination, he can appeal to a Board of Examiners who have the power to review the action of the Chief Examiner in charge of the application. If the applicant is dissatisfied with the decision of the Board of Examiners, he can then appeal to the Commissioner of Patents. He has two appeals. In some cases the Board of Examiners reverse the decision of the Examiner, and sometimes they affirm it. Decisions are sometimes reversed by the Commissioner. But the Examiners, in the several divisions, are men who have had a great many years' experience in the matter, and are well posted in the particular branches they are engaged in. It is very seldom that the decision of the Chief Examiner

in any department is overruled by either the Board of Examiners or the Commissioner, although it is sometimes the case when good reasons can be presented.

Usually a claim for an application consists of a good many claims. Whenever a claim is finally rejected and you are notified that an appeal will now lie to the Board of Examiners, it is about as well to stop there and save time and trouble, unless you can show very clearly that the Examiner-in-Chief is mistaken, and it is not easy to do that. I know in the department where I have had applications, that when I got a final rejection by the Chief Examiner, my attorneys have told me that it was not worth while to appeal from the decision, and I have accepted their advice.

President Grunsky.—One of the principal points in Mr. Richards' paper seems to be the fact that many of our manufacturing establishments rely upon the protection of letters-patent for their very existence and conduct of business. Any information on that subject, I think, would be of interest. It is somewhat new to me. I was surprised to hear so broad a statement.

Mr. G. W. Dickie.—I do not know that I have reached the stage when I would say that patents ought to be abolished, but my opinion is a decided one that the patent laws ought to be modified very thoroughly.

A patent is granted in this country if the Examiner can find no previous patent covering the subject. The examiners are not qualified to pass upon the newness of the subject; they are not qualified to pass upon the question as to whether it is an invention at all or not, but the examination has simply led to the determination whether this thing has already been patented. Therein, I think, lies the difficulty with patents. There are so many people who obtain patents for things that are not new, and that are not inventions; in fact, a very large majority of them are in common use every day; and there is no manufacturer of mechanical articles but is subject to a great deal of annoyance and trouble and hindrance in his work through the interference of these patents of things that are not inventions at all. This morning I got an injunction saying that I must not make any more piles of square timber with a sheathing of redwood, with felt between the redwood and the timber, because it had been patented; patent dated January 1, 1889. I told the party that we had been making these piles since 1883. He said, that made no difference; that we could not use them any more, or make them any more. I told this party that his patent was not a new thing; we did not consider it new when we used it; it was an old thing and quite familiar to all of us. He said, " You have no patent for it, and therefore you can't make

it." It is this ignorance on the part of inventors that gives the most trouble. We are continually beset with that kind of thing. Sometimes, rather than go to the expense of a lawsuit, we will pay something to get rid of the interference.

Then there is another class of patents that are granted for things that are in common use, and which affect patents already granted. This kind of patents are a gross injustice to all those engaged in mechanical manufacture. As some of you know, several years ago I designed a hydraulic dock for the Union Iron Works. There were a great many things about it that were practically new in dock construction; and, in fact, I may say here that every day, in a large engineering establishment, there is more real invention in regard to details of work than you will find for a month in the whole range of patents. In designing this dock I did not protect any of the new things I introduced in it. Some three years ago the Government engineers wanted to adopt my principles at the Cascades, and they came around and asked me if I would not make drawings for this slip. I had some drawings made for them simply as a matter of courtesy, which they very nicely acknowledged in the Government report. The draughtsman, while making the drawings, thought that in manipulating the valve it would be better to have the screw move through the nut instead of the nut through the screw. I had no objection, and I thought in some cases it might be better. Some two or three months after that I saw the publication of a patent that this man had taken out, as applied to hydraulic docks.

These things are very aggravating. He gets his patent because it had never been patented before. If the dock years ago had been patented, he could not have got the patent. And this kind of thing goes on every day, and those who have to bear it get very much irritated over the patent question.

I am against patents for the reasons I have stated. I took out a good many patents years ago, but I came to see the error of my ways in that respect and have given it up.

If there could be some way by which real inventions and real inventors could be rewarded without the manufacturing community being saddled with so much of this patent business, I think it would be a grand thing and a move in the right direction. If it were possible to have some kind of commission, composed of mechanics, to whom inventors could submit their inventions and let them decide whether the inventions were new, not whether they are patentable, it would be much more practical. There is all sorts of maneuvering and tricks to find something that is patentable, and therein lies all our trouble. It is not a fact that engineers are opposed to the rewarding of inventors for real inventions, but it is the multitude of tricks they are opposed to. A great many of the

so-called inventions are backed up by an appalling amount of ignorance. Probably more patents have been taken out on steamship propellers than any other device. Many of these propeller-patents are taken out by farmers. You see an old hayseed coming along with a roll under his arm, and he has a new propeller sure as fate. I know them by instinct.

I practically indorse all that Mr. Richards has said, but he does not touch the question as it touches the manufacturer. I do not think Mr. Richards is right when he makes the statement that most of the large manufacturing establishments are based on patents. I think most of the engineering concerns in the world are those that you never find mentioned in connection with patents.

President Grunsky.—I understood Mr. Richards' paper to state the reverse; that it was the smaller institutions that owe their existence to patents, and the larger manufacturing establishments are less dependent upon patents.

Mr. Dickie.—That may be the sense of the paper. There is no doubt but a very large number of small manufacturing establishments are founded on patents, and some of them are founded on inventions of great utility, and they deserve all they get out of them. But these are but a drop in the bucket compared with the deluge of useless patents that are not inventions.

I would like to make this distinction understood. What I am opposed to are patents, not inventions. I have talked with hundreds of engineers on this subject, and the general opinion among them is, that if we could avoid this deluge of worthless patents and reward the inventors of useful things, then the Patent Office would be of great benefit to the mechanical community.

Mr. Bowers.—I agree with the last speaker in pretty much everything he has said. There has been an immense number of worthless patents issued by the Patent Office, and are being issued every day. There are a host of people who watch the official *Gazette*, and the moment they see a patent for an invention that they think has merit, they immediately start in to devise some trifling modification and take out a patent for that, and, in making their application, they will make a drawing of the full invention. After having secured a patent for that little detail, they will go to some one that is not up in patent matters and show him the drawings, and say they have a patent for that invention, and nine people out of ten will take it for granted that the patent covers the invention shown, while the contrary is the case. The drawings shown of the patent are covered by the prior patent, and the subsequent patent covers only some trifling detail.

Then there are persons who get a claim on useless patents. It is astonishing what a number of worthless patents are sold, and the amount of money that is made by people who are not inventors, but who will devise a trifling modification of an invention and secure a patent for it.

There is another thing I wish to mention which I think ought to be incorporated into our patent laws, or into the practice of the office. A person will see a patent that covers a good invention, and he thinks he can make some small improvement on it. If the patent is a new invention, and has a broad claim covering all mechanical equivalents—or so broad that the art or the matter covering the patent cannot be practiced without violating the patent—a person may design some little device differing slightly from the original and claim that it is an improvement on the original, and the Patent Office gives him a patent for this improvement. Now then, that improvement is subject to the original invention, it is covered by the original patent in this sense ; that it is an infringement on the original patent. While it may be a good improvement, and the patent may be valid, still it cannot be used by the person making the improvement, because it is covered by the broad claims of the original invention. Now, in all such cases as that, a patent should be granted to the inventor, and he should be allowed to use it. As the law now is, he has no right to use it himself, because it is subordinate to the original invention. A great many people think that if they take out a patent for anything, then they have the right to use it. This is not the case with the class of patents I have just mentioned, and they will not have a right to use it until the original patent runs out.

The point I had in view was this: That in all cases where a patent is subordinate to a prior patent, it should be so stated in the patent itself, so that parties buying the invention might know that they would have to also buy the right to use it. There are a great many of such patents issued, and they are sold to parties who think they have a right to use them, and who honestly and in good faith go to work to operate under the patents and then find them subordinate to prior patents. All this could be largely avoided by stating in the patent itself that it was an improvement on another patent, subordinate to it and subject to the rights of the owner of that patent. This would save a great deal of litigation, and it would save thousands of innocent parties from investing money in that which they have no right to use after they have bought it.

PRESSURE AND IMPULSE IN MOTIVE ENGINES.

A Look Into the Future.

By John Richards, Member of the Technical Society of the Pacific Coast.

[Read January 4, 1895.*]

When a man of discerning tendencies has spent thirty to forty years engaged in what is called constructive engineering work, in an advanced environment, and when he has thus learned to understand contemporary practice, he is in position to render the highest possible service to the world by forecasting the future.

To do this to the best advantage he must withdraw from the activities of practice, and from personal interest in any particular thing or branch, and must impartially survey the whole field, weighing, measuring, and comparing, and considering what the trend is and what the future will probably bring forth.

Such prognostication is of the very highest value. No other contribution to the world's industry can have more value, even from an intensely practical standpoint. In fact, a great share of the highest human effort is devoted to prying into the future, and in endeavoring to find out what its future wants will be, and what is likely to supply these wants most acceptably. This prospective spirit is the essence, so to speak, of both commerce and manufacturers.

The most interesting and important part of such forecasting relates to physical discovery in the technical arts, and notably in those involving the employment of motive power.

These remarks are suggested by a letter lately received from Mr. Charles Brown, C.E., of Basle, Switzerland, containing some forecasts in respect to engineering matters.

Mr. Brown is one of the most eminent constructing engineers now living. This claim has authority far beyond the writer's opinions, but he can add the fact that for twenty years past he has watched with interest and profit every work and opinion emanating from this distinguished engineer. After a successful career, extending over an average lifetime, employed in constructing work as diversified perhaps as has ever fallen to the lot of one engineer, bringing to bear thereon a remarkable natural ability coupled with education and training of the highest order,

*Copy received April 25, 1895.—*Secretary, Ass'n. of Eng. Socs.*

he has now turned back to look over the field passed through, and to draw from it conclusions that deal with the future.

I have no authority to introduce Mr. Brown's name here, and none to quote from his letter mentioned, but it seemed necessary in the present paper to shield myself behind the opinions of one whose views are entitled to much more weight than my own.

Some of Mr. Brown's views, as I gather them from one or two paragraphs in his last letter, and hinted at in previous communications from him, may be stated in the following propositions:

(1) The utilization of the force of fluids, elastic and inelastic, will in the near future be mainly by impulse instead of pressure.

(2) The impulse of fluids, elastic and inelastic, will be utilized by means of rotary motors.

To render these propositions plainer, and to connect them with familiar practice, I will remark that they mean that steam engines, pumps, and blowing engines, like water-wheels and water engines, must abandon pressure upon pistons, and substitute the action of impulse upon wheels.

This does not mean that a revolution is suddenly to take place, but that the future tendency is to be in the direction, or, as we may say, is in that direction now, and to a greater degree than is commonly known or supposed. The proposition must also exclude special appliances, both for elastic and non-elastic fluids, and be confined to what may be called common pumps and motors.

I am not quoting Mr. Brown's words, or paraphrasing them, but am, to some extent, guessing at his opinions by inference.

Before speaking of the subject in its practical aspect, and as connected with modern engineering practice, some generalization may render it more clear.

Machinery to utilize the gravity of water in descending from a higher to a lower level; machinery to overcome the gravity of water and raise it from a lower to a higher level; and machinery to utilize the expansive force of water converted to steam, or, in other words, water-wheels, steam engines and pumping machinery, with their attendant elements, constitute a large share of what a mechanical engineer is called upon to study and deal with at this day, and it is to these the propositions before named relate. I will not detain you by statistics of the amount of steam- and water-power in the world, or its relation to transportation, travel, commerce, manufactures and even the social conditions of our times. This is too well understood to call for remark.

In the descent of water we have the choice of two methods for utilizing its gravity—pressure or impulse. The first represented by water-pressure engines, gravity or overshot wheels, and pressure-turbine wheels,

such as those of Fourneyron, Jonval and the American types of inward discharge wheels, all operating by pressure caused by obstruction to flow, or, as we may say, receiving pressure directly. The second, or impulse method, represented by the Atkins, Girard and Pelton wheels, operating from the impingement of jets set in motion by pressure, or, as we may say, by pressure in a second phase of spouting velocity.

The action of water in the case of enclosed or pressure-turbines is not, I am aware, resolved mathematically, as stated above, but this rendering is near enough for the present purpose, which is to show how the two methods of pressure and impulse have in water-wheel practice been contending for thirty-five years past, dating from the first impulse-wheels made by Messrs. Escher, Wyss & Co., of Zurich, Switzerland, about the year 1860. The principal facts of this rivalry will be again referred to.

In steam engines a similar struggle has begun between impulse and pressure. It is young yet, and lacks the history of water wheel practice, but the future problem is now well before us in both its theoretical and practical aspects, but has not advanced to a place in popular knowledge that permits general discussion.

At this time all popular ideas, as well as nearly all practice, is confined to pressure steam engines of both the piston, or reciprocating, and the rotary kind, mainly the former, but all operating by direct pressure and maintaining steam-close running joints around pistons. The construction and mode of operation is too familiar to require explanation.

In the other class of steam engines, the impulse kind, there is employed the efflux of steam-impinging against vanes that move at about 0.55 of the velocity of the steam, or thereabout; for an average 500 feet per second, or 30,000 feet per minute, according to the steam-pressure employed. In some cases discharged on the vanes at the initial or boiler pressure, in other cases expanded before impingement, down to atmospheric pressure, the effect being nearly the same, and as the mass, or ponderable weight of the fluid. The velocity is not diminished, and is even increased at this lower pressure by means we need not inquire into here.

Here we have a strange analogy between the application of elastic and inelastic fluids, between water and steam, and in a change from pressure to impulse action. The same laws apply in respect to the relative velocity of motors, the method of application is nearly the same; in fact, impulse water-wheels have, in some cases, been driven by steam.

The main distinction is in the respective velocities of efflux and consequent speed of the motors. For water we have $V = \sqrt{2 g H}$, and for steam $V = 60 \sqrt{T + 460}$, both in feet per second, or about as eight to one. At this pressure a steam-driven wheel to operate economically would have to attain, as before remarked, a speed of about 500

feet per second, 30,000 feet per minute, according to the steam pressure employed.

Before referring to the tendencies in present practice, and considering what the future may bring forth, I will point out that a first conclusion will be that all these things are amenable to computation, and can be solved mathematically. This is unfortunately not the case. Some of the conditions, and even the dynamic results, may be thus arrived at, and have been in the case of Parson's impulse steam engines, also Dr. De Laval's, but the main problems are of a constructive nature, pertaining to the maintenance of high velocities, balancing, lubrication and the elements of transmission.

Still it must be admitted that but little progress can be made without the aid of computation in verifying and explaining results, in so far as forces and resistances, but, as remarked, the chief problem lies in that branch of engineering we call constructive. For example, a theoretical steam engine would be one of the rotary type, sustaining direct pressure, and moving at velocities not at all attainable in such engines, even if they were a possible machine on other grounds, which they are not.

The strange proportions of parts would never have been resolved as they are found in practice either by inference or computation, but being found, then new light is added by theory; definite rules are arrived at, the direction and measure of inherent forces are made plain, the thermal conditions are explained, but first and mainly must come the constructive idea or design qualified by working conditions so obscure as to defy human skill until tentatively developed by long and tedious experiments, dealt with empirically, often blindly, and no small share arrived at by accident. This has been the common course in the past, and is now to a great extent the path followed, but in some instances progress has been the other way, not from construction, use and experiment, but in attempting to supply mechanism to accomplish certain computed results.

Pressure and impulse steam engines furnish two notable examples of these two methods of development. The first were a constructive and experimental problem throughout three-fourths of their history, before the study of thermal laws became a part of steam engineering. Then by both computation and a higher constructive skill the advance during twenty years past has produced our modern types, approaching nearly to ultimate efficiency for the pressure system as it now exists. The course of impulse-engine development is different. It starts with all the aids that have attended the final work on pressure engines, but on the whole the system or method has in ten years made nearly as much progress as the pressure or piston type did in a century, that is, from a steam consumption of 48 pounds per horse-power down to 14.5 pounds, or high

efficiency for modern expanding engine of the piston type. This matter is mentioned as one factor to be taken into account in forecasting the future and interpreting signs that increase from month to month.

Reverting now to the practical part, and first to water-wheels, we can easily follow the advance made in the impulse type. The first discovery and proposition of this method, so far as I can trace it, originated with Mr. Jearum Atkins, an American, now in his old age an inmate of the Mechanics' Home in Philadelphia. He presented his invention of open or impulse turbine wheels in the American Patent Office in 1853, where it could not be understood, and a patent was refused. He at that time filed in the office a complete analysis of the theory upon which these wheels operate, clear, concise, and to-day one of the most lucid descriptions that can be referred to.

In 1875, twenty-two years later, a patent was granted to him for the same invention; but before this time, about 1860, impulse turbine wheels had been taken up by some of the foremost engineers in Europe, and had become a standard type in France and Switzerland. At the present time, and for fifteen years past, no other form of water-wheels has been thought of there, or in other European countries, for heads exceeding fifty feet.

The practice is very uniform all over Europe, and the number of impulse wheels made must exceed pressure turbines three to one. The great wheels at Niagara are a modification of the Girard or impulse system, more nearly impulse than pressure wheels, the plans being supplied by Messrs. Faesch & Picard, of Geneva, Switzerland, who were among the early makers of Girard wheels.

On this Coast I need hardly say that tangential wheels, a purely impulse type, have displaced pressure turbines for all except low heads, with gain in efficiency, a saving in first cost and in maintenance. The impulse method has in fact been successful in all cases of competition up to a limitation by the volume of water that for constructive reasons renders the system inapplicable for low heads, and when wheels require to be submerged.

The change from pressure to impulse in water-wheels is, however, by no means so great a change as that between pressure and impulse steam engines. The initial velocity of water, or of wheels driven by this element, is the same in both cases, but with steam the initial velocity is changed, as we have seen, as fifty or sixty to one, giving rise to new and extraordinary differences. To make these more plain I will again enumerate with more detail the conditions of operating with pressure or piston engines.

The weight and space occupied by motive engines of all kinds are, as a rule, inversely as the velocity of the "actuating parts," and by such

a rule pressure engines should be fifty times the weight of impulse engines. The running joints or bearings for pistons, valve rods, valves, guides, connections, and so on, consuming from six to ten per cent. of the developed power in piston engines, are nearly avoided in the impulse type, but are to some extent, not known, balanced with losses by air friction on the impulse wheels. The elements of transmission between the piston and crank shaft have at all points throughout to withstand the full measure of strain imparted to the crank pin, not uniformly, but in a series of waves, to so call it, consequently these elements are about five times as heavy and expensive as when the initial movement corresponds to .055 that of the flow of steam. The change also simplifies such gearing.

Vibration, due to intermittent stress and reciprocating parts, is a serious objection and impediment in the pressure system. It calls for ponderous fastenings and foundations that with lavish plans and material, especially in vessels, is only partially successful.

Fly wheels have to be provided to equalize the variable turning moments in all land engines. This function is supplied in vessels by paddle wheels, screws and multiple engines, but a fly wheel of some kind is an essential part of an ordinary piston engine.

We have then in this case a motor moving at eight to ten feet a second, impelled by a fluid whose normal flow is eight to nine hundred feet a second; fifty times the weight, and ten times the space occupied that would be required if the steam could be directly applied. There is, however, one difference that must be kept in mind, that in engines driven by the impulse of steam a certain speed must be maintained, while in piston engines this is variable in any degree.

For most purposes this latter feature is not important, but is indispensable for traction, and we need not look for change in that branch of steam machinery. The same fault would in some degree apply in navigation where variable speed is necessary, as in the case of boats making frequent landings, but not for ocean service.

This difficulty in impulse engines arises from the fact that the flow of steam follows a different law from that of liquids, and is computed as a function of temperature, instead of pressure or head, varying only 35 feet a second between 25 and 100 pounds pressure, and only 10 feet a second between 100 and 150 pounds per inch, consequently speed cannot be controlled by volume.

But outside of all uses requiring variable speed there is left a much wider field for impulse engines, and considering the objections to the pressure or piston system before pointed out, we cannot wonder that men learned in these matters should set about finding out some escape from such sacrifices made to mechanical expediency. I am not able to

name but a few of the eminent engineers who have considered and are engaged in developing the impulse system for steam engines.

First may be named Dr. De Laval, of Stockholm, Sweden, inventor of the centrifugal cream separators, who, to impel these high speed machines, conceived the idea of a steam-driven impulse wheel, operating by the direct efflux of a jet applied on vanes. This, as we believe, was about ten years ago. The object was not efficiency or novelty, but a high initial rate of rotation to avoid transmission gearing. The result was so remarkable as to lead on to further experiments and results until a steam consumption as low as forty pounds per horse-power per hour was attained.

Then the matter began to attract attention, and the Hon. C. A. Parsons began, in England, a series of exhaustive experiments connected with careful computations of the thermal and dynamic conditions attending on the impulse method, and now, at the end of less than ten years, he has removed modern compound piston steam engines in the city of London, and replaced them with steam turbines, or impulse engines. This was done in one of the stations erected only a short time ago, and as Mr. Brown remarks in his letter before referred to, " is a most significant fact." It is more than a year since the editor of *Engineering*, a high authority, conceded that the impulse steam engine had attained the same efficiency as a compound piston engine.

Able engineers all over Europe have this problem in hand now, and if, as Mr. Brown writes, steam consumption has been reduced to 6.5 kilograms, or 14.5 pounds per horse-power per hour, the thermal problem is done, that is, the efficiency has overtaken the pressure engine, and now remains a development of various constructive problems that are almost sure to be rapidly worked out.

The speed of impulse engines follows the same law that applies to all motors driven by the efflux of fluids, the residual velocity, or, as we may say, the residual "rest," because there should be no velocity in the spent steam, is a resultant of two components, the movement of the fluid and that of the motor, the former being reversed in its course, and the relative speeds of the steam and the vanes or buckets being as 100 to 55. This rule produced in the first engines of De Laval and Parsons from 20,000 to 30,000 revolutions per minute. Five years of constructive effort has reduced these enormous velocities of rotation to one-third as much, and to a point where direct connection to the armatures of electrical dynamos is possible, and the required gearing of transmission is brought well within the resources of modern practice.

The conditions of operation in pressure or piston engines have been in part pointed out, and, as said, disclose the incentives that have led to the impulse method. Ultimate efficiency is not the object. This

cannot in the nature of things vary much between pressure and impulse. The force of efflux in fluids is equal to their gravity multiplied into their velocity, less the friction of orifices, and apparatus that will utilize the impinging force in the same degree that pressure is utilized by pistons will be equally efficient, other things being equal, so the objects to be attained by the impulse method for steam engines lies in another direction.

It will be revolutionary to institute complete comparison, and unfair in the present state of the impulse method, only ten years old, dating from the De Laval experiments. Steam consumption has fallen from 48 pounds to 14.5 pounds in that time, and from being a curious experiment the impulse engine has thrust itself in among its venerable competitors, not in obscure corners, but in high places. The electrical generators on the two greatest trans-Atlantic steamers are driven by impulse engines, supplied by Mr. Parsons about four years ago. There are many other cases that cannot be called to mind at this time.*

Other inventions of equal extent rise in these times, pass into the industrial field and soon disappear in the whirl of progress and change, that characterizes our age and time, but here is one of different nature and portent.

The application of motive fluids by impulse instead of direct pressure, that came about almost insensibly in water, means a wide revolution in steam, one that will not only modify constructively and economically nearly all that pertains to steam power, but will widen the field of application to hundreds of purposes, not now thought of.

Mr. Brown informs me that he is considering the application of impulse engines to traction purposes, but has naturally met with the impediment of variable speed, almost the only fundamental virtue inherent in the piston engine, and, as before said, confined mainly to this very case, so that he has attacked the exaggerated end of the problem, and will most likely abandon the scheme.

One other feature of impulse engines remains to be noticed. Expansion to the fullest degree must be a characteristic of any economical steam engine. This Mr. Parsons provided for at first in nine stages, and to transfer from one stage to the next involved a principal feature of objection to pressure engines, that of maintaining steam-tight running joints, not actual contact between surfaces in this case, but joints of such precision that while not in contact, no considerable leak could pass through them.

* During the first three months of this year, Mr. Parsons received orders aggregating 12,000 horse-power of his impulse engines. He has been compelled to call in the aid of other works, and at last accounts was operating his own night and day.—J. R.

This calls for an accuracy of work that cannot be attained with ordinary implements and by ordinary skill, but the De Laval engine avoids all this by a single application of the steam, first expanding it to the pressure of the atmosphere, and converting the expansive force into velocity.

This is, in my opinion, the keynote to the whole system, because engines thus made require no close running joints, and are simple in all their elements, down to the reducing gearing, and this, as now constructed, seems to operate without difficulty.

For eight years I have urged on all possible occasions the attention of engineers on this Coast to impulse steam engines, and their importance for special, if not general purposes. These propositions have been treated, like perhaps the present paper may be, as a visionary matter, but, however this may turn out, I am getting into very respectable company, and feel encouraged accordingly, hoping even to see at some future time an engine of 100 horse-power, wheeled on a hand barrow, a quiet, undemonstrative little machine that can be set in some corner out of the way on a common floor; also to see power distributed by impulse air engines over wide districts without much loss in transmission, without heat, danger, or the complication of electrical apparatus even.

This is, perhaps, enough for one occasion, all that it is safe to say, but having the floor I may as well go on and shock the engineering proprieties with the second preposition relating to impulse, laid down at the beginning. It was as follows:

"The impulsion of fluids, elastic and non-elastic, will in future be performed by impulse derived from the momentum of rotation."

This proposition, almost wholly new to me, comes in a rough pen sketch and some explanation by Mr. Brown, of what he calls the centrifugal pump of the late Emile Bourdon, an engineer whose name will be familiar to most of those present by reason of his other inventions relating to fluid action.

Fourteen years ago, when I undertook the construction of centrifugal pumps here in San Francisco, I was informed by people whose opinions were certainly to be considered, that pumps of that kind would not operate against heads exceeding forty feet, and they proved it too by rules, showing that an increase of resistances with head, fixed a commercial, if not practicable, limit at that pressure. Combining two pumps I found their force in series was multiplied accordingly, and a pump to operate against a head of eighty feet was made and operated successfully.

Single pumps have since then been made to raise water 160 feet without encountering the theoretical resistances commonly set forth in

authorities, and I have the boldness to believe that the theories applied to these pumps are wrong, and that what we call the centrifugal method of pumping has no such limits as have been fixed by computation. I presented in a previous paper before this Society the enormous increase of capacity, and a corresponding decrease in cost, of continuous flow pumps, and came near some predictions that if the paper were to be written now would form a portion of it.

Heretofore we have operated in one line of construction, or method, for generating what we call centrifugal force, or a force derived by rotation for impelling fluids, but if instead of centrifugal force we consider the momentum of revolution, and deliver this momentum impulsively to the performance of work, we are carried into a new field, and the limitations of centrifugal pumping will disappear, theoretically at least.

If a body of water is set in revolution by being dragged over large frictional areas by an impeller whose volocity at different radii cannot conform to that of the water, we cannot expect to impart to the water a very large proportion of the original energy, or driving power, employed to set the water in motion ; but if the water is gradually set in rotation, almost without friction or retarding influence, except its inertia, that water applied impulsively should give out again in useful effect within a few per cent. of the original energy or power. To do this the water should not be whirled around in a stationary vessel or case, but in one revolving at the rate desired for the water to attain, and the impulsive effect taken off, so to speak, by impingement on the fluid to be raised or impelled.

It is, perhaps, inexpedient and unfair to bring to the Society's notice a matter so little supported by tangible data at this time, but knowing that some of our members are now engaged in hydraulic problems, relating to the impulsion of fluids without the losses of intermittent motion, and as the Bourdon pump is an impulse machine, it cannot be passed by. The proposition involves both the generation and application of the pumping or impelling force, and there is, of course, no direct analogy to steam engines and water-wheels that draw from an accumulated store of energy.

The Bourdon scheme involves a translation, it may be called, of the energy as well as its application by impulsive effect.

Suppose that a cylindrical vessel like a centrifugal drying machine, having inward projecting vanes around its interior periphery, is filled with water, and set in revolution up to a velocity of 80 feet per second at the interior tips of the vanes. The water would then be moving at a rate the same as that produced by a head of 100 feet, and if this water could be diverted tangentially, and directly applied to the propulsion of other water to be raised or impelled, the losses would be

inconsiderable. To take off this revolving water tangentially a discharge nozzle has to be introduced inside of the revolving chamber. This discharge pipe would, of course, obstruct or prevent rotation of the water in the zone occupied, creating a frictional area equal to the width of the revolving chamber multiplied by a circle touching the end of the discharge pipe. This frictional area is not more than a third what is encountered in a common centrifugal pump, and is that of viscosity principally.

This indicates in words the experiments being tried by Mr. Brown, who, as I understand, proposes velocities far beyond precedent, or possible, with a common centrifugal pump. The same method can be applied to air or any other elastic fluid the same as water.

There may be present members who are familiar with the experiments and views of M. Bourdon. I will not pursue the matter further now, but with consent may at some future time lay before the Society some results of experiments now going on that may modify present views of the impulse method of translating energy.

DISCUSSION.

Mr. A. M. Hunt.—A brief description was given of a turbine steam motor invented by R. H. Hewson, of San Francisco, a number of which have been manufactured and tried.

The design of this motor is crude, and its economy not good, but there is no reason why, by a proper proportioning of the parts, an engine of good efficiency may not be made of it.

A patent lately issued to Mr. Hewson embodies the idea of multiple expansion of the steam through a series of buckets, in this way following the lines on which Parsons has been working.

ENGINEERING EDUCATION.

By Prof. L. S. Randolph, Member of the Association of Engineers of Virginia.

[Read April 17, 1895.*]

The analogy between the college or the university on the one hand and the manufacturing establishment on the other, is far more complete than is usually supposed.

The verdant freshman represents the raw material, the different undergraduate classmen the material in process of construction, and the graduate with his diploma the finished product.

As it is necessary that the manufacturer should carefully study the market in order to know the kind and quality of goods which the public and the exigencies of life demand, the method of manufacturing, that the most economical results may be obtained, and the raw material, that the best and most suitable only may be taken; so it is necessary that the educator should study the conditions of life to see what is required of the student; in what points he must be prepared, and with what degree of finish, the method of teaching, that the best results may be obtained, and the standard of admission, that he may obtain the desired quality of raw material.

The purpose of this paper is to discuss what knowledge will best fit the young graduate for the practice of his profession and what will best enable him to attain that *permanent* success in his profession which is the true end to be aimed at and which alone will repay him for the work of preparation and for the weary years of waiting and trial when his ability is being proven; and we will also discuss some of the methods which may be used to impart this knowledge.

Webster defines engineering as "the science and the art of utilizing the forces and materials of nature," and the engineer as a person skilled in the principles and practice of engineering, or one who carries through an enterprise by skillful or artful contrivance; an efficient promoter—a manager.

We see running through these definitions the idea of a manager or superintendent and not only the one who knows how; the idea of an executive officer, not only a consulting or directing officer.

The definition which seems to the writer to best fit the case is "one who applies the discoveries of the scientist to the needs of mankind," and we find this similar to a definition which can be readily gotten from

* Manuscript received June 7, 1895.—*Secretary, Ass'n of Eng. Socs.*

Webster's definitions: that is, one skilled in utilizing the materials and forces of nature.

From a recent catalogue of one of our most prominent schools of engineering we find the following disposition of its graduates:

Chief engineers of railroads, consulting and inspecting engineers, assistant engineers of railroads, city engineers	45	per cent.
Managers, superintendents, presidents and contractors	29	"
Engineering instructors	6	"
Other professions and indefinite positions	20	"

We find from the accepted definitions and statistics that we get the idea not only of the necessity for a thorough knowledge on the part of an engineer of scientific laws and natural phenomena, but of the best way also to apply them for the use and benefit of mankind.

The engineer must be not only thoroughly acquainted with the scientific facts, but he must have sufficient knowledge of economic principles and the ordinary facts of every-day life to apply them to the best advantage. How many of us, yielding to the fascination of scientific study and research, have awakened just in time to find that the scientist was strangling the engineer.

The time comes when the engineer must do the work which properly belongs to the scientist, and then, swinging to the opposite side of his orbit, do the work of the clerk or accountant.

The young man, thrown out on the world, can no more choose his pathway, as a rule, than the wreck on the wide ocean; but so long as he is able to hold to the profession of engineering, he should be prepared to take whatever work comes in his way, and in whatever part of the field of engineering it may lie.

Let us see what will be required of the engineering student.

We find the field of the discoveries of the scientist with which the engineer has most to do to be physics, chemistry, mathematics and astronomy. In physics—mechanics, heat, light, sound, electricity and magnetism.

Under the head of mechanics we have statics and dynamics of solids and liquids, and kinematics.

Under the head of heat we have conduction, radiation and reflection and the effect of heat in producing expansion.

Under the head of light we have refraction, defraction, reflection and the composition of light colors and polarization.

Acoustics—propagation of sound waves, its reflection and the interference of sound waves.

Electricity and magnetism—the relation between electromotive force, current and resistance, induction and magnetization.

Chemistry—the composition of bodies and the theory of their

reaction, both for organic and inorganic compounds; and under this head should be included the closely allied sciences of geology, mineralogy and metallurgy.

Mathematics, while only a tool, is so indispensable an implement that little could be done without it.

Astronomy we find of comparatively little use to the majority of engineers.

Under the above subjects we will find nearly all the fields for scientific investigation; and it is in these fields that the discoveries are made which it is the engineer's province to apply or make use of.

In the early days of engineering education it was deemed sufficient that the engineer should be thoroughly grounded in the above, that is, he should understand the scientific side of the question only. As the subject of engineering education was developed, three different schools were evolved: The German or Continental, the English and American.

In the German or Continental the theoretical side of the question was given the greatest prominence and the student was thoroughly drilled in this side of the question rather to the exclusion of the other.

In England the opposite system was developed and the student was given a practical problem and drilled in that; his work leading him back to the scientific principles involved.

In the United States the system of instruction which has been developed may be said to be a combination of these two systems, a mean between the two extremes. The student is thoroughly grounded in the elements of mathematics, physics, astronomy, and chemistry, and from this he is lead to their application to engineering problems, especial attention being paid to those subjects which are of greatest importance in the particular branch which he wishes to follow, whether civil, mechanical, mining, military or electrical, and the examples used for applying these principles are drawn from practice in the particular branch under study.

That this system of giving the student instruction, in the method of applying the facts which he had learned, was a long step in the right direction, will, I am sure, not be questioned, in the face of the marked success of the technical schools in this country. But the detail of this work; what to leave out and what to put in and how far certain subjects should be carried in the different divisions is a matter which has been much debated, is being debated, and will probably be for many years to come. Probably no two men could be found who would agree, or whose practice would harmonize, each one working toward that goal which he thinks will bring greatest benefit to his pupil and reflect the greatest credit on himself.

All of our colleges are limited to a certain given time, usually four

years, within which the student must be taken with a certain amount of knowledge and brought up to such a state of knowledge as will enable him to reach the standard demanded by his degree, and the problem is to use this time to the greatest advantage possible as an illustration:—

Should the theory of arches, bridges and foundations be taught to the mechanical, electrical and mining engineer, and if so, how far should it be carried and to what extent should its application be taught? That the civil engineering student should be carried further goes without saying; but how much further? In some colleges the courses in this particular are almost identically the same. In others, all but the civil stop with the theory of the subject. The writer's experience has lead him to believe that the latter is the correct practice.

Again, should the civil engineering student be taught thermo-dynamics, and its applications to the steam, air and gas engines and to refrigerators? All these are absolutely essential to the mechanical engineer. The theory of thermo-dynamics should, of course, be taught, but should its applications also be taught to the civil or mining engineering student? In the writer's own experience several cases have arisen where civil engineers have had pressing need of a knowledge of refrigerating processes, but it would seem that the percentage of such cases is not great enough to warrant requiring each student to go over all of this work to the exclusion of other work in the line of his specialty.

The question of chemistry frequently comes up for the mining or metallurgical engineer. A thorough knowledge of inorganic chemistry is absolutely essential; but for the civil, mechanical or electrical, how much and to what extent should it be carried? Should these last two have organic chemistry and any work in biology? Should either one take up water supply or sewage work?—such knowledge would be extremely valuable and can scarcely be dispensed with; but with this important exception, the engineer, it may be said, does not have sufficient use for these subjects to pay him for spending the time over it.

Should the mechanical engineer alone, as having to do with the design of machinery, be taught the principles of machine design? It is almost universally acknowledged that the application of the discoveries in the field of electricity were held back for years by ignorance of the subject on the part of those who designed the first electrical machinery. So that we can say that for the electrical specialist, as well as for the mechanical, it is absolutely essential; but does the civil or mining engineer have use for this particular knowledge? Some rather amusing designs would indicate that they do not all get it.

It is freely acknowledged that the theory of the subjects given above should be carefully brought out; but to what extent should their application be taught, and from what source should the problems illustrating

their application be selected? It is here that the differentiation starts between the branches of engineering education, and it is after this that the principal difficulties of the problem present themselves.

As has been said before, it will scarcely be denied that the plan of teaching the application of theoretical and natural laws, and the drawing of deductions from observations upon them, was a great step in advance, but is there not another step which can be made? Having made the application to a given definite problem, should we not also bring out and determine the principles which govern the value of the problem when solved?

Having studied and observed the action of the discovered natural laws, and having applied the information so obtained to the solution of problems, should we not also carry the student to such a point as to enable him to determine what problems are worth solving and what their value will be in dollars and cents when solved? For the world measures the efficiency of the engineer in dollars and cents.

WOODEN BRIDGE CONSTRUCTION ON THE BOSTON AND MAINE RAILROAD.

By J. Parker Snow, Member of the Boston Society of Civil Engineers.

[Read May 15, 1895.*]

The subject of iron and steel bridges has been quite extensively written up in our technical literature during recent years, but wooden bridges are seldom discussed, and when mentioned, are generally treated as temporary structures or excuses offered for their use. The building of such bridges is, however, a live business on the Boston and Maine Railroad, although the impression seems to be prevalent in many quarters that such construction is obsolete and out of fashion.

This paper is offered to describe the present practice in wooden bridge construction on the above-named railroad, and if not considered as in line with present approved practice elsewhere, may at least have some interest as a history of one branch of the bridge-building art.

On the system operated by the Boston and Maine there are 1,085 wooden bridges of all kinds in a total of 1,561. This number covers overhead as well as track bridges and includes everything of 6 feet clear opening and upwards, except stone box culverts. The proportion of wooden bridges grows less each year, although more than half of the new structures built to replace old bridges are built of wood.

The types most commonly used for new work are pile trestles, plain stringer bridges, compound stringers made of timbers keyed together to get greater depth than is possible with single sticks, pony trusses of the Queen post and Howe type, and Town lattice bridges. At the present prices of iron bridges Howe trusses of considerable span, if built in first-class shape of Southern pine timber, cost almost exactly the same as iron ones and consequently are practically ruled out. A considerable number of stringers trussed with rods beneath are in existence, but are seldom built at the present time.

Spruce timber is used for all parts of Town lattice bridges, and for caps, stringers and ties in many trestles and plain stringer bridges on Northern lines. On lines south of Central New Hampshire, however, Southern pine is almost invariably used. Spruce is sufficiently durable when roofed in, and on account of its lightness is much better than Southern pine for lattice trusses, but its softness and tendency to warp and the difficulty in getting sticks of sufficient length make it unsuited for Howe truss work of magnitude. For bottom chords of lattice bridges of over 100 feet span, recourse must be had to Southern pine also on

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account of the difficulty in getting spruce of the requisite length. Tamarack, oak and chestnut are used for piles in trestles.

The life of sawed spruce exposed to the weather is but about six or seven years. Southern long-leaf pine of prime quality in similar conditions is reliable for twelve to fourteen years. When covered in and well ventilated and kept free from accumulations of dirt, either timber will last forty to fifty years. Sawed chestnut for ties, stringers, etc., is about intermediate in durability between spruce and hard pine. It has been used for bridge timber on the Southern lines of the system considerably in years past, but is not so used now and is not recommended.

Tamarack piles in dry land trestles will last eight to ten years, chestnut and oak of good quality fifteen to twenty.

The loads used in calculating new wooden bridges are somewhat lighter than the standard used for those of iron. It is thought that wooden bridges are necessarily of a less permanent character than iron ones and that within their natural life the weight of rolling stock will not increase so much above what it is at present as may occur in the life of an iron bridge; again, if wooden bridges are found to be too light for future loads, they can be strengthened, or supported on trestle bents much better than iron ones, and a wooden bridge, like a piece of masonry, will give abundant notice of distress before it will fail entirely. The governing reason for building wooden bridges instead of iron ones altogether is, of course, their less first cost, and if the full standard load for iron bridges was used in designing them this element of advantage would be reduced and they would be no more serviceable or satisfactory for present use than if designed for the lighter load. The load used is a train of consolidation engines weighing, each, with tender, 172,000 pounds, with 24,000 pounds on each driving axle, or 80,000 pounds on two axles, seven feet apart. This is somewhat in excess of engines in use at present on this system, and although considerably lighter than the load used in designing iron bridges, the considerations given above seem sufficient to justify its use.

The usual unit strains used are, for Southern pine 1,000 pounds per square inch direct tension and 800 compression; the latter, of course, reduced for ratio of length to diameter. For spruce this unit is taken at 650 compression and 800 tension. For fiber strain in stringers and beams the unit is 1,200 pounds per square inch for both hard pine and spruce. The reason for adopting this figure for spruce is that in exposed situations, as is the case with stringers, the life of spruce is so short that it is a waste of material to provide for the much talked about increase in engine loads, and while sound, this unit gives a very satisfactory bridge. For combined transverse and longitudinal strain two-thirds of the former is added to the latter and 800 pounds used as the unit. Longitudinal shear-

ing is kept below 80 pounds per inch and transverse crushing on hard pine from 350 to 400 pounds per square inch, depending on whether the whole width of the stick is covered or only a small area.

These unit strains are used for new work; an old bridge will, however, stand up and carry its load when the computed strains in some parts are very high. Of the three classes of bridges built twenty years ago, iron pin, iron riveted and wooden, all of which figure equally neai the danger limit, common prudence will select the pin bridge as the first one to be removed, the riveted one next and the wooden one, if sound, last.

The cost of bridges for single track of 120 feet span will compare something as follows:—Iron $5,300. Howe truss of Southern pine and iron angle blocks $5,000, and spruce lattice $3,500. Below this span, the advantage of wooden bridges over iron ones in point of cost will increase and above it the advantage rapidly reduces to nothing.

The standard spacing of bents in pile trestle bridges is 15 feet. Solid caps drift-bolted to the piles and girder caps with riders are used indiscriminately, the former being the cheaper and the latter making the most rigid structure. The stringers used on these trestles are for single track, two 8″ x 16″ under each rail and one of the same dimensions on each side placed 10 feet apart from outside to outside. The stringer sticks are 30 feet long, laid to break joints; the two sticks under each rail are spaced 2″ apart by cast iron spool separators and ¾″ bolts, four at each cap. The stringers are secured to the caps by drift bolts. The floor consists of ties 6″ x 8″ x 12 feet long, laid 4″ apart in the clear. Tie spacers 6″ x 8″ are placed flat on the ends of these, notched down one inch and bolted to every fourth tie. These bolts have a round burr washer under the head on top and a Warren nutlock for washer at the lower end. The floor is kept in line by occasional lining spikes or drift bolts through the ties into the side stringer.

The tie floor above described is standard for all wooden bridges; it is shown in cross-section Fig. 1. In designing, the ties are considered as

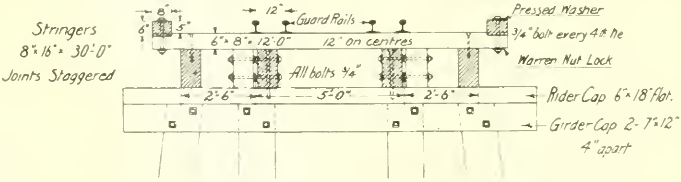


Fig. 1. Standard Trestle; 15 Ft. Bent.

distributing the load so that 80 per cent. is carried by the main stringers and 20 per cent. by the side ones. The continuity of the stringer sticks over two spans is considered as reducing the moment of the load at the centre of span by 10 to 12 per cent.

Plain stringer bridges are built the same as above described for trestles, except as the stringers do not have the advantage of continuity over supports, the sections must be larger for similar spans. The depths of the sticks should not be less than $\frac{1}{12}$ to $\frac{1}{14}$ the span.

When the span becomes too great for merchantable depths of timber, or convenient thicknesses, recourse is had to keyed stringers. These are made by placing one stick on top of another and framing cast-iron keys between them, as shown in Fig. 2. A vertical bolt at each key prevents the timbers from separating.

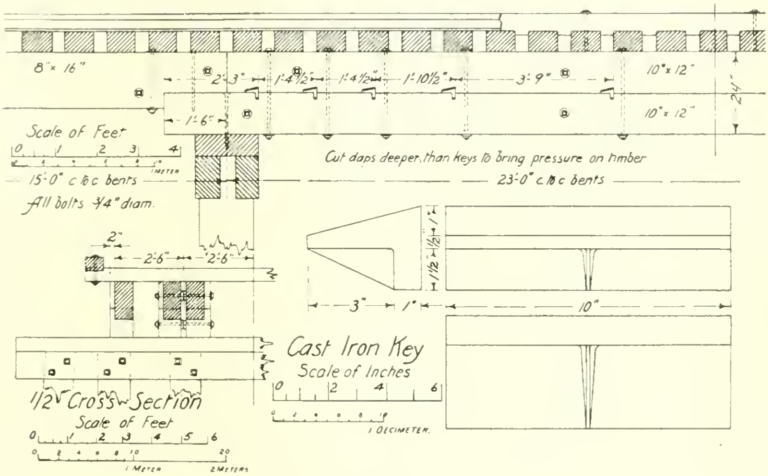


FIG. 2.

These keys are proportioned for the longitudinal shear, and hence the total depth of the compound stick can be used in computing its moment of resistance. The keys are cut $1\frac{1}{2}''$ into each upper and lower stick, and an attempt is made to distribute them according to the intensity of the shearing strain; but near the ends of the stringer a strict adherence to this requirement would bring them so near together in some cases that the daps might split out. With notches $1\frac{1}{2}''$ deep, it is desirable that they should be at least $18''$ apart. The quantity of longitudinal shear at the neutral axis, between any point and the end of a beam, is a function of the fiber strain at that point; being equal to $\frac{b.d.f.}{4}$ when b. is the breadth, d. the depth and f. the extreme fiber strain. A convenient way to locate the position of the keys is to draw a line the ordinates of which represent the moment of the load and lay off to some convenient scale, $\frac{b.d.f.}{4}$ as an inclined ordinate at the center of this curve. Now, beginning at the base, space off on this inclined line the value

of each key, and draw horizontals through the points of division; these horizontals will cut the moment curve into spaces showing the proper field for each key. The friction between the two sticks, induced by the load and by the grip of the vertical bolts, helps to resist the longitudinal shear, and a proper proportion can be added to the value of the key when spacing off the inclined ordinate.

These stringers require considerably more material than trusses of equal strength, but the labor on them is small and they can be put in place and prepared for the passage of trains in much less time than trusses. This latter quality is of great importance, and should be given more attention by bridge designers than it generally receives. This style of bridge works in with the ordinary trestle spans very conveniently when it is desired to make a wide opening for a runway for ice or logs, or for a highway underpass. The lower stick of the compound stringer is extended beyond the upper one to furnish a seat for the regular stringers of adjacent bents. In cases, too, where the trestle bents are high and expensive it will lessen the cost of the structure to make alternate spans compound or keyed stringers. This style of bridge is available up to clear spans of 30 feet.

Pony trusses are used for spans between 30 and 60 feet, generally of the Howe type. For overhead highway bridges requiring trusses modified pony Howe trusses are used almost exclusively. For these latter and for track bridges it is altogether better to use floor beams, distributed along the chord about 2½ feet apart, rather than to concentrate the load at panel points by means of stringers carrying the load to large floor beams, as is done in iron bridges, and it is generally best to hang the floor beams below the chord. If the plank floor of highway bridges is laid directly on these cross floor beams it brings the plank parallel to the line of travel; this is considered objectionable, and hence longitudinal spiking joist or stringers, 4 to 6 inches thick, are laid on the cross floor beams and the plank spiked to these. On bridges carrying light traffic a single 3″ floor is used, but where the travel is heavy it is economical to use a double floor, generally 2″ below and 3″ for wearing surface. The under plank lengthens the life of the floor very considerably by keeping it safe for a long time after the corners of the upper plank have worn through.

Railroad bridges of this class should always have the top chords stayed against side motion, as shown in Fig. 3, and it pays to protect the trusses from the weather by sheathing and roofing them in.

For spans greater than is desirable for pony trusses the Town lattice built mostly of spruce is our only resource. As before stated, Howe trusses of Southern pine cost almost as much as iron bridges at present prices. Spruce, the only available timber growing in the region in

which these bridges are used, is not well adapted to Howe truss work, but is excellent for lattice bridges. This style of bridge seems never to have been developed to much extent outside of New England, and it is fre-

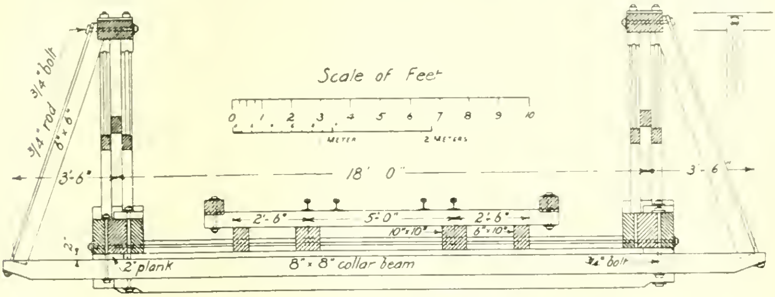


FIG. 3. SWAY BRACING FOR PONY TRUSSES.

quently referred to as peculiarly unscientific and wasteful of timber. It is, however, the best of the purely wooden bridges, and its present survival here and its economy over all other types disproves its wastefulness. These trusses should always be built double, that is, with two webs like a box girder. Single web trusses can be made strong enough up to 80 feet span, but they do not stand so steadily or keep in line so well as those with double webs. The distance between the webs is immaterial, but is generally made equal to the thickness of two chord plank, from 6 to 8 inches. Outside of the webs, it is not deemed advisable to use more than three thicknesses of plank on each side; this confines the chord to 8 planks, and as this is generally not sufficient to give the requisite strength, a second chord is added at the second web intersection. These second chords serve not only to carry chord strain, but also to stiffen the diagonals and to assist the outer chords to distribute the shear between the tension and compression members of the web.

The chord strength of these trusses is computed by assuming the distance between the centers of outer chords as the effective strain depth of the truss, and reducing the section of the inner chords in the ratio of the squares of their distances from the neutral axis. In the case shown on the inset this ratio would be nine-sixteenths. In several bridges of this type now standing on the Boston and Maine road, built in former years, there are three sets of chords, but the third chord has but little theoretical value, and judging by the amount that the joints are pulled they assist but little in carrying the chord strain. The proper arrangement of the breaks in the planks of the lower chord affects the strength of the whole much the same as the arrangement of eyebars affects the strength of pins in an iron bridge.

In bridges of 125 feet span and upwards it becomes necessary to fasten the abutting ends of the chord plank together and the device

shown on the inset is used for this purpose. The gib-bars are wrought iron, varying in section with the thickness and width of plank to be joined; hexagon nuts are used on the yoke rods so as to necessitate as little cutting of the chord stick as possible. A ribbon is sometimes put between the webs at the middle height of the truss, as shown in the inset, with the idea of stiffening the web and preventing vibration.

DISCUSSION.

Mr. B. W. Guppy.—The Town lattice truss was patented in 1820 or 1821. The inventor, Mr. Ithiel Town, published pamphlets in 1821 and 1831, describing the bridge, and the claims that he makes therein as to the economy and durability of this type of bridge have been fully substantiated. Copies of these pamphlets are in the possession of the Boston Public Library.

Some of the advantages that Mr. Town claimed for his bridge are as follows:

"Suitable timber can be easily procured and sawed at common mills, as it requires no large or long timber.

"Defects in timber may be discovered and wet and dry rot prevented much more easily than could be in large timber.

"There is no iron-work required, which at best is not safe, especially in frosty weather."

This last statement is rather amusing, as Mr. Town previously states that the trusses can be built either of wood or iron. Moreover, it is due to a free use of iron that the present development of the bridge has been obtained.

Iron is used principally in the form of bolts and rods, and its use increases the strength of certain parts like the tension chord, and allows of adjustments to take up the shrinkage of the timber.

Wedges at the ends of the pins or treenails were used to keep the sticks in close contact. Bolts at the intersections of chords and lattice are now used for the same purpose, and they also add to the strength of the chord connections.

Iron chord couplings add a large percentage to the strength of the tension chord.

A Howe truss system of lateral bracing is used instead of the Burr system originally adopted, and by means of turnbuckles on the rods placed so as to be easy of access, adjustments can be made to keep the trusses properly in line.

Formerly the floor beams in through bridges rested on top of the bottom chord, bringing most of the load on the inside chord sticks and web

system. The present practice is to hang the floor beams below the bottom chord by hanger bolts alternately on opposite sides of the chord, as shown on the drawing accompanying Mr. Snow's paper. This distributes the load equally between the two web systems and adds an amount to the headroom equal to the depth of the chord plus the depth of the floor beam.

Some of these bridges have a very long life. One that was taken down on the Boston and Maine system last year and replaced by a similar structure was claimed to be over fifty years old, although no exact record could be found. This refers to the trusses. The floor was newer, having been renewed and strengthened. The timber was in fairly good condition, extreme lightness of construction being the principal cause for renewal.

Another bridge taken down the year before was over forty-five years old.

In use these bridges stand a great deal of abuse. A butting collision on the approach to one bridge piled the cars of one train up through the roof. Beyond breaking a hole in the roof, and cutting up a few ties, no damage was done to the bridge. Another collision in which only one train participated, the bridge acting as a buffer, resulted in considerable damage to the end vertical and web; but the bridge is still in use without any repairs and is considered to be perfectly safe. In another case logs at high water broke off the ends of the lattice. Bolts were put in connecting the floor beams with the upper lower chord, relieving the lower joints of all vertical load, and as they are still strong enough to transmit the chord stress, the bridge is used without any apprehension of danger. This bridge has the floor beams resting on top of the bottom chord. If they had been hung below they would have protected the ends of the lattice.

During the recent floods in New Hampshire, a pier was washed out from under a two-span bridge. As the invariable practice is to make these bridges continuous over all intermediate supports, the bridge was saved.

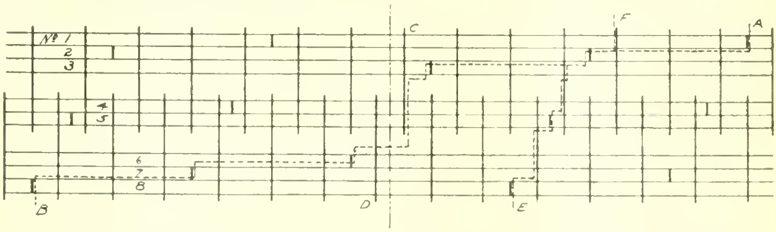
At the same time the abutment was washed out under the end of another bridge, causing one of the trusses to settle several feet. It was blocked up into place and is now in use, the flexibility of the construction preventing any serious damage.

Fire is the principal enemy of these bridges, but the danger has become much less since the introduction of coal burning engines. The fires usually start in the roof and are generally extinguished before they do any damage to the trusses. A good coat of white-wash together with water barrels, buckets and a ladder at each bridge are the means of protection.

The road has these bridges insured, but as fatal fires are so few, and the losses are generally so small, it would seem to be economy to have the road do its own insuring.

In designing this truss, the practice is to use a panel length of from four feet to four feet six inches, the panel length being the distance between the chord pinnings for one of the lattice systems. The pinnings of the second lattice system are half way between those of the first. This brings the distance between two pinnings equal to one half a panel length. The panel length is taken at such a length within the limits given as will bring the total number of panels equal to $n + \frac{1}{2}$ where n is any integer. This arrangement brings the center line of truss halfway between two pinnings, making the chord stick cuts symmetrical, and making the odd length sticks the same at both ends.

The method of arranging the cuts in an eight-chord stick is shown in the accompanying diagram.



In figuring the strength of the tension chord, the following assumptions are made:

(1) When there are four pins and one bolt at a pinning, the net area of the stick is taken as the depth in inches minus five, multiplied by the width.

(2) The value of a pinning to transmit stress between two sticks is taken as 1,100 pounds for each pin and 600 pounds for one bolt, making a total of 5,000 pounds for one pinning of four pins and one bolt.

These values were arrived at by figuring the pin for bearing, shearing and bending; the limiting value being given by the strength of the pin to resist bending. The lever arm was taken a constant of 1.3 inches for the three thicknesses of plank generally used, namely $2\frac{7}{8}$, $3\frac{3}{8}$, $3\frac{7}{8}$, as the flexibility of the pin must cause the load to be concentrated near the inner edge of the stick and the examination of pins taken from old bridges seems to justify this assumption.

When wrought iron chord couplings are used, the strength of a coupling is the net value of four $\frac{7}{8}$-inch rods at 10,000 pounds per square inch, or 16,920 pounds.

When chord couplings are used, there are two cases to consider: (1) when the strength of one coupling plus three pinnings is less than the net strength of the stick, and (2), when it is greater.

In the second case, the weakest center section is practically straight across the chord on the line $C\,D$. In the first case, the minimum value of chord is along the line $A\;B$. There is also a section $E\,F$, $1\frac{3}{4}$ panels from the center, the strength of which should be investigated, as in some cases it has a less value than the center section.

In the bridge shown in the drawing, the bottom chord is composed of six 14 x $3\frac{7}{8}$-inch sticks and two 14-inch x $2\frac{7}{8}$ sticks. Net value of one 14 x $3\frac{7}{8} = 9 \times 3\frac{7}{8} \times 1000 = 34{,}875$ pounds.

One coupling = 16,920 pounds,
Three pinnings = 15,000 "

31,920 " which is less than net stick and the minimum center section will be along the line $A\;B$.

Stick 1	1 coupling	3 pinnings	31,920
" 2	1 "	3 "	31,920
" 3	1 "		16,920
" 4	net stick	14 x $2\frac{7}{8}$	25,875
" 5	"	"	25,875
" 6	1 coupling	1 pinning	21,920
" 7	1 "	3 pinnings	31,920
" 8	1 "	3 "	31,920
			218,270 lbs. net value of center section.

Section $1\frac{3}{4}$ panels from center

Stick 1	1 coupling	3 pinnings	31,920
" 2	1 "	1 pinning	21,920
" 3	net stick	14 x $3\frac{7}{8}$	34,875
" 4	"	14 x $2\frac{7}{8}$	25,875
" 5	1 pinning		5,000
" 6	net stick		34,875
" 7	net stick		34,875
" 8	1 coupling		16,920
			206,260 lbs. net strength of chord $1\frac{3}{4}$ panels from center.

With sticks 16 inches deep and the same widths the center section will have a value of 229,770 pounds, and the other section 235,260 pounds, being the greater in this case Inspection shows that the strength of the center section is increased only by the increase in sticks 4 and 5.

This span is about the limit of this style of bridge without the use of an arch, although spans have been built up to 150 feet

The shear is assumed to be uniformly distributed over all the web planks cut in a given section. The members are so thoroughly pinned

together that they cannot possibly act as single independent systems to be separately calculated as is advocated in some text-books, but the strain must be equalized throughout a vertical section much as would be the case with a solid web.

A lattice truss should extend well on to the masonry. For reasons connected with the proper construction of the floor this extension on the abutment should be about one and one-half panels; a solid bolster should be placed under the chord for this distance and under this should be the cross wall blocking. The compression diagonals near the end of the truss deliver their shear to very short tension members; the fastenings of these do not seem to be able to carry the load delivered to them, and the bolster is needed to help take the thrust of the compression members direct. Many old bridges built probably without much knowledge where the maximum shear occurs have failed by having the bottom chord split down or literally sheared at the edge of the wall plate by this action. Proper bolsters would have largely prevented this. It is the custom now to put solid posts between the webs at the end and second panel points extending the whole depth of the truss. These cut through the two middle plank of the chords and would endanger shearing the bottom chord if the bolster did not extend beyond the cut-off. These solid posts furnish a substantial support to pin the short ties to and to receive the compression members which do not reach the bottom chord. None of the trusses built in this way have shown indications of weakness in the way explained above. The panels should be between 4 feet and 4½ feet and the web plank should be given inclinations of nearly 60° with the horizontal.

The pins used in these bridges are 2″ oak. They should be of well seasoned timber, and should be carefully turned so as to drive tightly when the bridge is erected. Much depends on the pins. In old and weak bridges the pins are frequently found much distorted. In heavy trusses all plank must be at least 12″ wide in order to take four pins at the chord intersections. At the web crosses two only are used. At all chord intersections and some in the web a ¾ bolt is used to hold the plank firmly together. This bolt is deemed of great importance from its preventing the plank from opening, which would greatly increase the leverage on the pins. It is possible that iron pins perhaps of heavy pipe rather than solid bars would mark an advance over the present practice, but they have not yet been tried so far as the writer is aware.

The floor beams in these bridges are at present invariably hung below the chord, two beams per panel. The ends of the web plank projecting below the chord are cut into to allow space for each floor beam. They are hung by bolts passing through the open spaces in the chord and through washer blocks on top of same.

The lateral bracing is the Howe system, that for the lower chord being laid directly on top of the floor beams, and the stringers cut over it; 5″ by 8″ to 12″ is the size generally used. The main stringers under the rail are 10″ by 10″ and the side stringers 6″ by 10″.

The load used for floor beams is 5,500 pounds per lineal foot of track, which is assumed to cover both the live and dead loads. Eighty per cent. of this is assumed to be on the main stringers and 20 per cent. on the side ones. The clear width in these bridges is 15 feet. This makes the effective length of floor beams 18 feet or more and calls for sticks so large that it is best to use Southern pine for them. Spruce can be readily obtained of sufficient size, but when so large and in so exposed a situation it twists and checks badly. Southern pine is used also for bottom chord plank for spans greater than 100 feet, and should always be used for bolsters and wall plates. The stone parapets of all through wooden bridges are brought in so as to be flush with the face of the abutment (see inset). This serves to protect the timber floor from the weather, obviates the large amount of blocking needed on the stonework when it is not so done, and shortens the bridge floor.

Lattice bridges are built on the Boston & Maine Railroad as above described up to 150 feet clear span. They are, however, rather unwieldy at this length and it is preferred for spans above 125 feet to build them with an arch inserted between the webs. These arches are built up to the required section with 2″ or 3″ plank and bolted to the trusses at every lattice cross which comes in contact with the arch. They abut against the stonework below the lower chord on large Southern pine skew-backs scribed to the stone. The skew-backs are mortised out in steps to receive the square ends of the planks. The planks of the arches are well spiked when laid and radial bolts are freely used to bind them well together. The load is brought upon the arch by vertical rods passing through the arch and down through the lower chords and floor beams.

The arch is proportioned to carry its own weight and the whole live load on the bridge. The trusses are made of the same section as those of one half the span which have no arch. These compound bridges are very satisfactory, being rigid under traffic and of more pleasing appearance than when built without arches. They are also much more economical of timber than simple trusses for the reason that the arch uses timber wholly in compression, in which condition the entire section is available; whereas when timber is called upon to act in tension a large portion of the section must be wasted in making the connection.

In order to secure a satisfactory track surface after several years' use, there must be considerable camber framed into lattice bridges. For trusses without arches, there should be 1″ for each 25′ of span and for those with arches 1″ for about 37½′ of span.

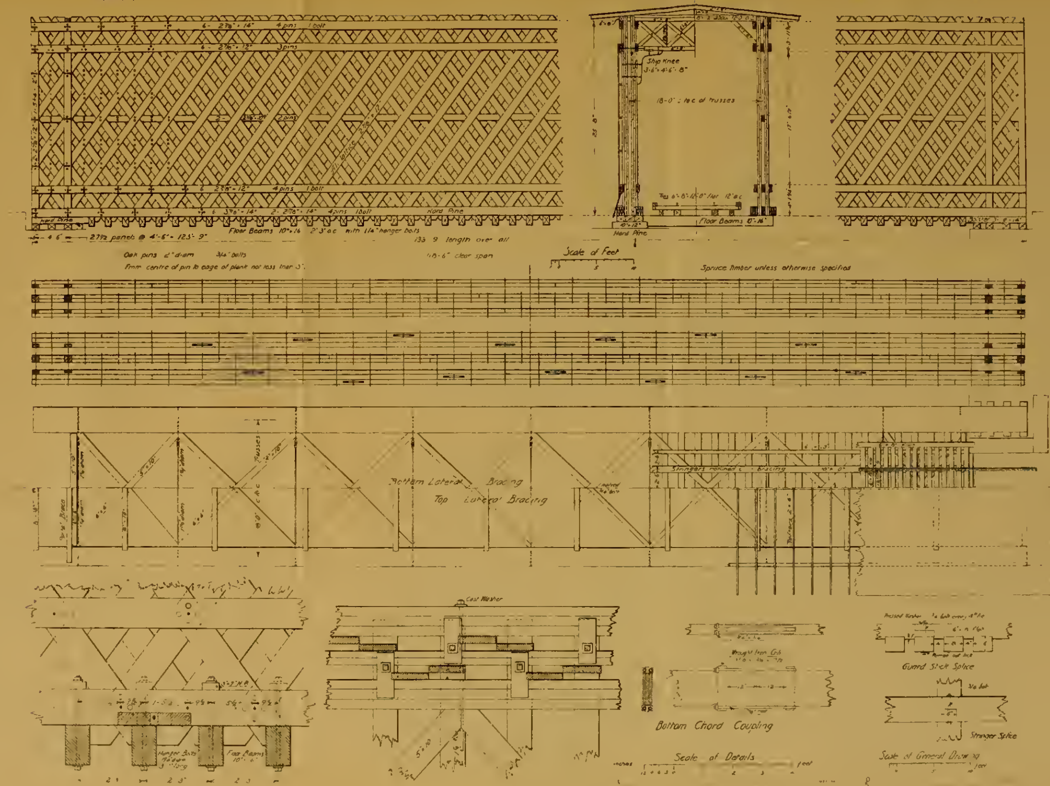
The lattice bridge has been described thus at length, partly because it has not been so fully treated as other styles in technical literature, and because it is the only kind that can be built in competition with iron at present prices. On the Boston & Maine system, there are many Howe and Pratt bridges, a few Burr, Briggs and Child's trusses and many of mongrel type; but the Town lattice has a large plurality over any other kind and there seems to be ample and good reasons for its natural survival.

These bridges as built to-day are, in all their important details, direct descendants of, and very near kin to, those built in years past by the bridge carpenters of Northern and Central New England. Those built by David Hazelton and his men furnish the basis of the present practice on this road and although they were built without engineering advice, they bear analysis well, with the possible exception of the bottom chords.

It has come within the observation of the writer many times that when an intelligent master-carpenter has had the care for a term of years of a line of wooden bridges covering any given style of truss, he gradually brings their parts, when building new ones, to almost the exact size called for by scientific analysis when actual loads are used in calculation. He will use iron rods that are too small for they show him no distress unless they break, but the timber parts guide him to right results.

It is this property of a timber bridge, its certainty of giving warning of approaching weakness, that has kept the record of wooden truss bridges so clear from fatal disasters. It is not reasonably safe to use a light iron bridge until it is worn out, but a wooden one may be used till its deterioration is rapidly approaching the end. Neither is it safe to entrust light iron bridges wholly to the care of workmen not technically educated; the timber parts of wooden ones may be.

It is no part of the intention of this paper to advocate building wooden bridges instead of properly designed iron ones, but rather to describe the favorite styles now used on those parts of the Boston & Maine Railroad where wooden bridges prevail, and to show that these styles are not so obsolete as seems to be supposed in some quarters.


Ship Knee
18'-0" c. to c. of trusses
Hard Pine
Floor Beams
27 1/2 panels @ 4'-6" = 123'-9"
133' 9" length over all
118'-6" clear span
Oak pins 2" diam 3/4" bolts
From centre of pin to edge of plank not less than 3".
Scale of Feet
Spruce timber unless otherwise specified
Bottom Lateral Bracing
Top Lateral Bracing
Cast Washer
Bottom Chord Coupling
Guard Stick Splice
Stringer Splice
Scale of Details
Scale of General Drawing

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BRIDGE DEFLECTIONS.*

By Malverd A. Howe, Member of the Engineers' Club of St. Louis.

[Read May 15, 1895.†]

The object of the following paper is to present the data and results of a series of experiments made to determine the effect of moving loads upon two railway bridges of about 122 and 164 feet span respectively. Many experiments have been made in this country and in Europe to determine the maximum vertical deflection of bridges under moving loads, and, in some cases, the lateral deflection; notably in experiments made by Professor Robinson,‡ but, in nearly all cases, as far as the author is informed, little or no data were determined in connection with the dimensions and weights of the moving loads, the true position of the moving load at the instant of maximum deflection, etc. In Professor Robinson's experiments, the speed of the moving load was determined by observers, making it possible to compute the true position of the load. In many cases the weights and dimensions of the cars and locomotives were obtained from the railway companies.

The majority of the diagrams represented in the tables accompanying this paper are automatic continuous records (for the point of the bridge being considered) of the following conditions:

1. The actual vertical motion of the point independent of the lateral and longitudinal motions.
2. The actual lateral motion of the point independent of the longitudinal and vertical motions.
3. The actual longitudinal motion of the point independent of the lateral and vertical motions.
4. Seconds of time.
5. The instant each wheel entered the span.
6. The instant each wheel passed the point being considered.
7. The instant each wheel left the span.

DESCRIPTION OF APPARATUS.

To obtain the above records the following described apparatus was employed, of which Fig. 1 represents an end view, Fig. 2 a rear view, and Fig. 3 a top view.

* The results embodied in this paper were obtained by Messrs. Rose and Tinsley, in 1892, and Messrs. Andrews and Hildreth, in 1894, in connection with their graduating theses. The apparatus was constructed to a great extent by these young men in the shops of the Rose Polytechnic Institute.

† Manuscript received June 22, 1895.—*Secretary, Ass'n of Eng. Socs.*

‡ Trans. Am. Soc. C. E., Feb., 1887. This is probably the most complete and valuable paper upon Bridge Vibrations which has ever been published.

Commencing at the bridge with any pin as *g* Fig. 1, a U-clamp *f* was securely fastened to the pin by the set screws *h*; to this clamp, which was slotted in the front face, the brass arm *d* was fastened by means of a bolt and thumb nut, so that the long arm was approximately opposite the center of the pin, thereby making the arm, to all intents and purposes, move in all respects with the bridge.

For transmitting vertical motion the adjustable arm *e* was fastened to *d*, the lower end of *e* bearing against the pin in lever *a'* (clearly shown in Figs. 1 and 3). Care was exercised to have *e* vertical, so that neither lateral nor longitudinal motion would move the lever *a'*; the lever *a'* transferred any vertical motion to the lever *a*, connected with the pen block *n*, which transferred the movement to the paper on the cylinders *k*, *l* and *m* (Fig. 3).

The arms of all levers being made equal, the record obtained was true size.

For lateral motion the bent lever *c* was employed, a pin in one end bearing against the plate *o*, Fig. 3; placed right angled with *d*, thereby eliminating the effect of vertical or longitudinal motion. The motion was transferred by the pen-block *n* to the paper.

Lever *b* transferred the longitudinal motion, the pin in one end moving in a slot in the arm *d*, as shown in Fig. 3.

The pen-blocks *n* moved on two round rods against spiral springs which effectually did away with lost motion of every kind.

In the above particulars it is believed that this apparatus is different from all others which have been employed. Nearly all, if not all, the devices employed by experimenters in this line have recorded the movements as arcs of circles and furthermore have not separated the individual movements. The rigid connection of the machine with the bridge is also a peculiarity of this apparatus.

The devices for recording the wheels and time require no description further than this: that all were dependent upon electric contacts.

The paper upon which the records were made was wound upon roller *m* passed over roller *l* and wound upon roller *k*. A crossed belt between *k* and *m* kept the paper taut by the friction between the belt and the rollers.

The roller *k* was fitted with a gear-wheel which was driven by a worm actuated by an $\frac{1}{8}$-horse-power electric motor. The speed of the paper was about one inch per second. The pens employed were made of glass and filled with red aniline ink. The paper employed was a very tough sketching paper, but of such quality that the records could be blue-printed when red ink was used.

The entire machine was supported on an adjustable telescopic box which rested upon a light portable scaffolding made after the plan of oil

derricks, but assembled with bolts. This as well as the lower chord details of the Big Four Bridge are clearly shown in Fig. 4.

Fig. 4 shows the floor beam connections, lateral connections and post details as well as the machine ready to work.

Fig. 4.

DESCRIPTION OF BRIDGES.

Two bridges were examined which are briefly described as follows

Vandalia Bridge.—This was the west span of the bridge over the Wabash River at Terre Haute, Ind., on the T. H. V. and St. L. R. R. The principal dimensions of the trusses are: span, 164 feet; depth, 26 feet; length of panel, 20.5 feet. The bridge is a single-track, through, of the Pratt type, having floor-beams riveted to the posts and stringers riveted between the floor-beams.

The floor-beams are 4 feet deep and the stringers 3 feet in depth. The floor consists of the ordinary style of ties resting upon the stringers with wooden guard timbers on the outside of the rails.

The track crossing the bridge is practically straight and level, the west approach is straight for several hundred feet, but the east approach is curved until within 100 or 200 feet of the bridge, but since the span considered was the west one the approaches for 800 feet in either direction were straight.

About 200 feet east of the easterly span the road is crossed by a north and south track, and hence all trains going west come to a stop some 300 or 400 feet east of the bridge.

All east bound trains stop for this crossing 200 or 300 feet west of the span considered. All engines were working steam when crossing the bridge.

All records were taken at the lower chord-pin in the center of the north truss.

Big 4 Bridge.—This was the east span of the bridge over the Wabash at Terre Haute, Ind., on the C. C. C. and St. L. R. R. The principal dimensions of the trusses are: span, 122.5 feet; depth, 24 feet; length of panel, 17.5 feet. The general design is the same as the Vandalia Bridge, the floor system, however, being reinforced by safety stringers of wood and an inside guard-rail of old rails. The floor-beams are 3 feet deep. Fig. 4 shows the general details of the bridge.

The east approach to the span considered is straight track, but on a down grade. The west approach is across some five similar spans, including a draw-span, upon which the track is straight and level. All records were taken at the lower chord-pin, three panels from the east end of the north truss.

ROUTINE FOLLOWED IN THE EXPERIMENTS.

The apparatus having been put in position, the electric contacts, pens, etc., were tried and all imperfections corrected, then all hands busied themselves waiting for a train to appear.

As soon as a train was discovered approaching every man went to his post of duty. One man was required at the instrument to watch

the pens and start the motor (the machine usually being started a few seconds before the train reached the span), and two men took the numbers and types of the engine and cars. After the train had passed the motor was stopped and all data obtained, including the date, were immediately written upon the diagram. In many cases an observer was stationed at the depots who made a memorandum of the car numbers, wheel bases, etc.

BIG 4 BRIDGE.

Vertical Motion caused by Engines.—Usually only the engine and one car was on the bridge at the time of maximum deflection, though for eastbound trains one truck of a second car may have been upon the span near the end; but this car could influence the deflection but little, so its weight has not been included in the tables. All of the records at the first glance indicate a considerable vibration while the engine was on the span, but a closer examination indicates that the irregularity or roughness of the record is due not so much to the vibration of the bridge as to the friction of the pen or the levers, as the irregularities are in steps, both during the time of increasing deflection and decreasing deflection. In only two cases out of twenty-two records was there sufficient evidence of vibration at the maximum point of the diagrams to warrant any note of same; these were diagrams 77 and 83, where the increase in deflection was but 5.1 and 7.5 per cents. respectively; in both cases the amplitude of the vibration being about 0.06 of an inch. The direction in which the train was going had no effect upon the vertical motion.

It is to be noticed that for the same engine followed by the same tender and car that the vertical deflection is very nearly the same in all cases; this, of course, might be expected in the results given, as there is but little variation in speed, with the exception of diagrams for engine 92; this was a yard engine *pushing* two coal cars, and the speed varied from 0 to 20 miles per hour.

The static deflection was found to be 0.39 of an inch.

The maximum departure from this was 0.04 of an inch with the train going east at a speed of 18.5 miles per hour; either this is an accidental result or all conditions were favorable for vibration, as a speed of 20.1 miles per hour caused no vibration at all, and, furthermore, when the train was going west no vibration appeared, although the speed was nearly the same.

Apparently, in diagrams 63 and 75, two engines weighing the same followed by mail cars give contradictory results, as the train having the heavier car gave the smaller deflection. This can be explained in several ways. The engines being different, may not weigh exactly the same; the tenders may have been differently loaded and the amount of mail matter quite different in the two trains.

Conclusion.—For this span of 122.5 feet, divided into seven panels of 17.5 feet each, the engine causes no appreciable or dangerous vibration in the main trusses at the time of maximum deflection for speeds between 0 and 20 miles per hour.

Vertical Motion Caused by Cars and Lateral Motion Caused by Cars and Engine.—The lateral motion in all cases, with hardly an exception, was a maximum for the engine.

The records are rough and irregular, with little indications of period, though close examination and a little stretching of the imagination shows that the bridge swings from side to side between two and three times per second for all trains and all speeds.

Cumulative vibration was quite frequent for the cars, especially in freight trains, when the cars were very considerably different in loading; this cumulative vibration took place usually when the greatest disturbance in the vertical motion was experienced.

The amplitude of the side motion for the speeds observed was about constant, as the speeds varied but little.

The records for vertical motion for the train were very smooth, and in only two cases was there indication of vertical vibration, and these were questionable.

The loaded and empty cars were easily distinguished by the records.

The maximum deflection due to the train was, with hardly an exception, not greater than three-fifths that due to the engine, tender and one car.

Conclusion.—For this span of 122.5 feet, divided into seven panels of 17.5 feet each, the train causes no noticeable vertical vibration in the main trusses, but the engine, as well as the cars, creates an irregular side motion.

Longitudinal Motion.—In all cases this was towards the roller end of the span, as might have been expected; small in magnitude and of but little interest.

VANDALIA BRIDGE.

Vertical Motion caused by Passenger Engines.—As in the case of the Big 4 Bridge, the records were rough, indicating some vibration as the engine entered the span, but at the point of maximum deflection very little vibration appeared, the maximum effect being an increase in deflection of 9.25 per cent. for diagram 21*a* for an eight-wheel Pittsburg engine weighing 89,000 pounds.

Conditions of loading being the same, the vertical deflection remains constant for trains going in the same direction, but a marked difference was found to exist between the deflections for east and west bound trains,

the latter causing much greater deflections. This, however, is readily explained as the west bound trains were heavier and the engines had just left the round house and commenced their run with full tenders while the east bound engines were at the end of their run with but little in their tenders.

This may seem questionable, but it must be remembered that an empty tender usually weighs about the same as the water and coal it is intended to carry. This means a difference of from 10 to 15 tons in the weight of the tender on the road.

Some of the roughest records due to engines have been reproduced. The records for engines of Class "B" (including the maximum increase of 9.5 per cent. in Diagram 21*a* mentioned above) show the effect of direction; the east bound records showing a much smaller deflection than those for west bound trains. The records whose numbers have a subscript were taken in 1892 and show a somewhat different characteristic than those for 1894. This is not easily explained.

The records for 1892 are more indicative of vibration while those for 1894 show steps which indicate friction in the apparatus.

The record for engines of types C, F and G have also been reproduced. The characteristics of the records are the same for all classes, there being no method in the madness of the curves, the slight departure from smooth lines appearing at random, sometimes indicating vibration and again only friction of the machine; in all cases, however, the swing or amplitude of the vibration, if it can be so called, appears to be very small in comparison with the maximum deflection due to the engine.

Conclusion.—Based upon these records, it is evident that passenger engines cause no injurious vibration in the main trusses of this bridge.

Vertical Motion caused by Freight Engines.—The effect of these engines is practically the same as for passenger engines with a more frequent tendency to vibration.

Diagram 33*a* (reproduced) for engine 160 comes nearer indicating a regular vibration than any other, yet this cannot be called cumulative and is very small in amplitude.

Diagram 28 for engine 267 (reproduced) clearly shows the effect of friction in the machine.

Conclusion.—The same as for passenger engines.

Vertical Motion caused by Yard Engine 92.—This engine weighing 66,000 pounds on four drivers and about 40,000 pounds on the tender, was run at speeds varying from 11.6 to 36.9 miles per hour to determine if speed would affect the records.

This engine at all speeds gave rough records, but the amplitude of the vibration was small and not a maximum with the maximum speed.

The average vertical deflection was practically the same for all speeds varying between the limits of .280 and .305 of an inch and these extremes occurring at practically the same speed.

The application of brakes appeared to have no effect.

PASSENGER TRAINS.

Lateral Motion due to Cars and Engines.—The lateral motion, in all cases, was a maximum for the engine, though now and then the cars caused a little, especially the rear cars. In no case did the amplitude exceed one-half of an inch.

The speed had a marked influence upon this record, the greater the speed the greater the amplitude and the more irregular the records. This is clearly shown by the records reproduced.

Engines of the same type also had quite different effects as shown in Diagrams 25*a* and 21*a* for engines 142 and 185 of type *B* moving at practically the same velocities.

FREIGHT TRAINS.

Lateral Motion due to Cars and Engines and Vertical Motion due to Cars.—Here the records were practically the same for the engines as for passenger engines, but quite different records for the cars, vibration being quite frequent and the rear cars nearly always producing more or less disturbance. Diagrams 28, 44, 54, 18 and 33*a* have been reproduced as being the best examples of records having lateral motion due to cars.

The vertical disturbance due to cars was also quite different in many cases, a *small* cumulative vibration being quite frequent. This is well illustrated in Diagrams 54 and 33*a*.

This cumulative disturbance seems to be due not to the length of the car as measured in panel length of the bridge, but to the loading of several adjacent cars. The cause is hard to determine with certainty. The disturbance exists and the only question which can be discussed is, does this disturbance cause any serious damage to the structure?

Lateral Motion due to Engine 92.—These experiments certainly show that the amplitude of the lateral motion or swing varies almost directly with the speed, a speed of 36.9 miles per hour causes a lateral swing of .305 of an inch ; as great as the vertical deflection.

Vertical Motion due to Pullman Cars.—The deflection caused by Pullman cars was practically constant and averaged about 0.36 of an inch.

Comparison of Theoretical and Actual Deflections.—The actual and theoretical deflections were compared for both bridges and it was found

that the actual was very much smaller than the theoretical deflection which was computed by Professor Johnson's $\frac{pul}{E}$ formula.

Of course Professor Johnson's formula assumes that the structure is purely pin-connected, that is, each member of the truss is independent and only connected to the truss of which it forms a part by pins. Is this the case with the bridges in question? Certainly not, for the top chord is practically a continuous beam from hip to hip and the bottom chord must be seriously affected by the lines of stringers which form a continuous beam from two to three feet in depth from end to end of the bridge.

Owing to the continuity of the stringers the panel loads then are not of the magnitude usually assumed, and which were assumed, in the calculations. This might materially affect the stresses in the main-truss members, and hence the theoretical deflection. Again, owing to the continuous top chord and stringers, may it not be questioned if the $\frac{pul}{E}$ formula is exactly correct, or even approximately correct, for the two bridges considered?

GENERAL DISCUSSION OF RESULTS.

Taking the records from both bridges as a whole there seems to be no indication of injurious stresses in the main truss members due to vibration produced by the moving load. The vibrations produced by the engines were exceedingly small, and that due to the cars, although greater in amplitude than that due to the engines, yet it always took place when the vertical deflection was much less than that produced by the heavy engines, so that the only injurious effects were those due to increasing and decreasing the stresses at the rate of about four times per second now and then. The range of stresses, however, being a very uncertain quantity.

For bridges of dimensions and types similar to those examined it does not seem necessary to add any material to the main truss members to provide for impact, according to the almost universal custom, and the author is of the opinion that the vibration of bridges, slight as appears for these two bridges and as large as Professor Robinson states in his paper for some bridges, may be entirely destroyed by putting in the proper floor system.

A very heavy and rigid floor, such as those designed to be ballasted with broken stone, or a very flexible floor hung to the chord pins, would without doubt consume all impact before it reached the main trusses.

The records of side motion indicate lateral weakness, and this is probably the case with all bridges of this type. The lateral motion is

caused, without doubt, by the nosing of the engine and the moving from side to side of the track of the cars owing to the widening of the gauge. The ordinary adjustable lateral system, designed to withstand wind only, is too light to resist this impact; the solid floor ballasted would probably overcome this weakness.

At some future time it is hoped that the device used in these experiments may be applied to bridges of various spans and designs, with known loads moving at various speeds, as the writer believes records similar to those exhibited would determine some points in bridge design which might be changed with advantage to the life and working of the structure.

Another point which would be interesting to examine is the deflections simultaneously of both trusses. The records suggest that the whole bridge may have taken a slight twisting or spiral motion.

The author wishes to acknowledge the very courteous assistance given by the officials of the Vandalia System, the C. C. C. and St. L. Ry. Co., the Pullman Palace Car Co., the Wagner Palace Car Co., Baldwin Locomotive Works and the Pittsburg Locomotive Works, and also for the assistance in collecting and tabulating results by Mr. M. C. Andrews.

TABLE I.—VERTICAL MOTION.

Passengers and Freight Engines—Big 4 Bridge.

Reference Number.	Date.	Number of Engine.	Type of Engine.	Weight on Pilot Wheels.	Weight on Drivers.	Total Weight of Engine.	Weight of Tender.	Car Following Tender.	Weight of Car Following Tender.	Max. Vert. Def. due to Engine.	Av. Vert. Def. due to Engine at Max. Point.	Percentage of Increase due to Vibration.	Approximate Speed in Miles per hour.	Direction.
69	May 4, 1894	196	8 W	39,900	79,700	119,600	85,240	Comb. car 113	50,000	0.54	0.54	. . .	20.4	East
B	" 3, 1894	196	"	39,900	79,700	119,600	85,240	" 118	53,500	0.55	0.55	. . .	20 9	West
A	" 3, 1894	197	"	39,900	79,700	119,600	85,240	" 113	50,000	0.57	0 55	3.6	31.9	East
66	" 4, 1894	197	"	39,900	79,700	119,600	85,240	" 113	50,000	0.57	0.57	. . .	23.1	West
70	" 3, 1894	116	"	33.000	55,300	88,300	60,000	Baggage 57	37,400	0.36	0.36	. . .	22.0	East
63	" 4, 1894	287	"	33,000	55,300	88,300	60,000	P. O. 8	52,000	0.38	0.38	. . .	24.6	West
75	" 3, 1894	379	"	33,000	55,300	88,300	60,000	P. O. 4	46,000	0.43	0 43	. . .	24.7	West
72	" 3, 1894	111	"	30,500	51,000	81,500	58,000	Baggage 63	52,000	0 42	0.42	. . .	19.6	East
64	" 4, 1894	299	"	22 900	63,300	86,200	63,900	Box	. . . . . .	0.42	0.42	. . .	19.5	West
76	" 3, 1894	300	"	22,900	63,300	86,200	63,900	Empty coal	. . . . .	0.39	0.39	. . .	17.2	West
62	" 4, 1894	450	10 W	29,900	103,700	133,600	82,650	Box	. . . .	0.58	0.58	. . .	15.2	East
77	" 3, 1894	450	"	29,900	103,700	133,600	82,650	"	. . . . . .	0.61	0.58	5.1	20.6	West
68	" 4, 1894	?	. . .	. . .	. . . .	. . .	. . .	"	. . . . . .	0.58	0.58	.	8.9	East
73	" 3, 1894	408	10 W	29,900	103,700	133,600	82,650	"	. . . . .	0.58	0.58	. . .	16.2	East
60	" 4, 1894	435	. . .	. . .	. . .	. . . .	. . .	"	. . . . . .	0.59	0.59	. . .	17.9	West
74	" 4, 1894	442?	10 W	29,900	103,700	133,600	82,650	"	. . . . . .	0.59	0.59	. . .	19.8	West
67	" 4, 1894	455	. . .	. . .	. . . .	. . . .	. . .	"	. . . . . .	0.55	0.55	. . .	18.3	West
84	" 3, 1894	92	6 W	. . .	104,500	104,500	61,600	Pushing 2 coal cars	Weight of coal cars.	0.39	0.39	. .	. . .	. . .
83	" 3, 1894	92	"	. . .	104,500	104,500	61,600	"	. . . . . .	0.43	0.40	7.5	18.5	East
81	" 3, 1894	92	"	. . .	104,500	104,500	61,600	"	. . . . . .	0.39	0.39	. . .	20.1	East
80	" 3, 1894	92	"	. . .	104,500	104,500	61,600	"	No. 1, 23,200	0.39	0.39	. . .	19.3	West
82	" 3, 1894	92	"	. . .	104,500	104,500	61,600	"	No. 2, 21,440	0.38	0.38	. . .	19.9	West

TABLE II.—VERTICAL MOTION.

Passenger Engines.—Vandalia Bridge.

Reference Number.	Date.		Number of Engine.	Total Weight of Engine.	Weight of Tender.	Weight of Car following Tender.	Maximum Vertical Motion.	Average Vertical Motion.	Percentage of increase due to vibration at Max. Point.	Approximate speed in miles per hour.	Direction.	Wheel Base of Engine.	Distance between forward Pilot and rear Tender Wheels.	Number of Pilot Wheels.	Number of Drivers.	Diameter of Drivers.	Maker.
31a	April 28, 1892	A	4	60,600	44,000	37,350	0.36	0.34	5.9	24.6	East	21′ 3″	43′ 8″	4	4	64″	Danforth Loco. & Mch. Wks.?
49	" 28, 1894		254	60,600	44,000	37,350	0.34	0.34	. .	11.1	East	21′ 3″	43′ 8″	4	4	64″	
20	" 26, 1894		254	60,600	44,000	37,350	0.31	0.31	. .	11.5	East	21′ 3″	43′ 8″	4	4	64″	
7	" 25, 1894		254	60,600	44,000	37,350	0.32	0.32	. . .	11.5	East	21′ 3″	43′ 8″	4	4	64″	
43	" 24, 1894		254	60,600	44,000	37,350	0.40	0.39	2.6	13.5	West	21′ 3″	43′ 8″	4	4	64″	
12	" 25, 1894		254	60,600	44,000	37,350	0.40	0.40	. .	19.0	West	21′ 3″	43′ 8″	4	4	64″	
25	" 26, 1894		21	60,600	44,000	37,350	0.39	0.39	. .	22.0	West	20′ 8½″	45′ 0″	4	4	62″	
33	April 27, 1894	B	142	89,000	59,500	P.C.C. Ex.	0.37	0.37	.	4.8	East	20′ 7″	44′ 2″	4	4	66″	Pittsburgh
22a	" 27, 1892		185	89,000	59,500	P.C.C. Bag.	0.42	0.40	5.0	13.5	East	22′ 9″	45′ 5″	4	4	66″	
21a	" 26, 1892		185	89,000	59,500	P.R. Comb.	0.58	0.54	9.2	23.0	West	22′ 9″	45′ 5″	4	4	66″	
25a	" 28, 1892		142	89,000	59,500	P.R. Comb.	0.54	0.50	5.0	23.3	West	20′ 7″	44′ 2″	4	4	66″	
47	April 28, 1894	C	145	65,000	49,000	41,400	0.33	0.33	.	12.0	East	21′ 1½″	. . . . . .	4	4		Baldwin
28a	" 27, 1892		143	65,000	49,000	61,200	0.39	0.38	2.7	14.5	East	21′ 6″	. . . . . .	4	4		
13a	" 27, 1892		145	65,000	49,000	P.C.C. P.O.	0.36	0.35	2.9	17.6	East	21′ 1½″	. . . . . .	4	4		
26a	" 27, 1892		143	65,000	49,000	61,200	0.42	0.41	2.4	17.0	West	21′ 6″	. . . .	4	4		
14a	" 28, 1892		145	65,000	49,000	47,500	0.41	0.41	7.3	28.4	West	21′ 1½″	. . . . .	4	4		
16	April 25, 1894	D	162	63,000	49,000	57,300	0.36	0.36	. . .	13.5	East	22′ 0½″	44′ 0″	4	4	68″	Baldwin
5	" 25, 1894		161	63,000	49,000	41,400	0.32	0.32	. . .	13.8	East	22′ 0½″	44′ 0″	4	4	68″	
14	" 25, 1894		161	63,000	49,000	41,400	0.36	0.36	. .	15.6	West	22′ 0½″	44′ 0″	4	4	68″	
15a	" 26, 1892		163	63,000	49,000	61,200	0.42	0.40	5.0	23.1	West	22′ 0½″	44′ 0″	4	4	68″	

40	April 27, 1894		181	84,600	59,500	38,400	0.39	0.39	. . .	6.9	East	22′ 9″	44′ 10½″	4	4	68″	
15	" 25, 1894		179	84,600	59,500	?	0.40	0.40	. . .	9.3	East	22′ 9″	44′ 10½″	4	4	68″	
9	" 25, 1894		181	84,600	59,500	?	0.40	0.40	. . .	10.6	East	22′ 9″	44′ 10½″	4	4	68″	
20*a*	" 28, 1892		179	84,600	59,500	?	0.38	0.38	. . .	10.7	East	22′ 9″	44′ 10½″	4	4	68″	
27	" 26, 1894		182?	84,600	59,560	?	0.39	0.39	. . .	12.0	East	22′ 9″	44′ 10½″	4	4	68″	
26	" 29, 1894		179	84,600	59,500	56,000	0.40	0.40	. . .	12.0	East	22′ 9″	44′ 10½″	4	4	68″	
24*a*	" 26, 1892	E	180	84,600	59,500	38,600?	0.44	0.415	6.0	19.8	East	22′ 9″	44′ 10½″	4	4	68″	Pittsburg
32	" 27, 1894		180	84,600	59,500	?	4.48	0.48	. . .	18.4	West	22′ 9″	44′ 10½″	4	4	68″	
48	" 28, 1894		179	84,600	59,500	38,600?	0.47	0.47	. . .	20.7	West	22′ 9″	44′ 10½″	4	4	68″	
34	" 27, 1894		182	84,600	59,500	?	0.46	0.46	. . .	21.0	West	22′ 9″	44′ 10½″	4	4	68″	
19*a*	" 27, 1892		179	84,600	59,500	?	0.52	0.50	4.0	21.7	West	22′ 9″	44′ 10½″	4	4	68″	
55	" 28, 1894		181	84,600	59,500	70,600	0.52	0.52	. . .	22.7	West	22′ 9″	44′ 10½″	4	4	68″	
24*a*	" 26, 1894		181	84,600	59,500	77,800	0.53	0.51	4.2	25.2	West	22′ 9″	44′ 10½″	4	4	68″	
52	April 28, 1894		187	105,000	59,500	38,400	0.43	0.43	. . .	7.3	East	23′ 5″	46′ 10″	4	4		
23	" 26, 1894		187	105,000	59,500	P. O.	0.47	0.47	. . .	10.0	East	23′ 5″	46′ 10″	4	4		
23*a*	" 27, 1892		186	105,000	59,500	P.R.R. P.O.	0.46	0.45	2.2	10.4	East	23′ 5″	46′ 10″	4	4		
18*a*	" 28, 1892	F	187	105,000	59,500	P.R.R. P.O.	0.48	0.465	3.2	16.5	East	23′ 5″	46′ 10″	4	4		Pittsburg
42	" 27, 1894		187	105,000	59,500	70,600	0.54	0.54	. . .	15.3	West	23′ 5″	46′ 10″	4	4		
30	" 26, 1894		186	105,000	59,500	30,200	0.53	0.52	1.9	19.7	West	23′ 5″	46′ 10″	4	4		
11	" 25, 1894		187	105,000	59,500	77,800	0.56	0.54	3.7	21.3	West	23′ 5″	46′ 10″	4	4		
51	April 28, 1894		191	139,000	80,800	P. O.	0.54	0.54	. . .	13.3	East	23′ 8″	50′ 7″	4	6	72″	
38	" 27, 1894		192	136,000	80,800	P. O.	0.55	0.55	. . .	13.8	East	23′ 8″	50′ 7″	4	6	72″	
8	" 25, 1894		192	139,000	80,800	P. O.	0.53	0.53	. . .	13.9	East	23′ 8″	50′ 7″	4	6	72″	
21	" 26, 1894	G	191	139,000	80,800	50,000	0.58	0.56	3.6	11.5	East	23′ 8″	50′ 7″	4	6	72″	Pittsburg
24	" 26, 1894		192	139,000	80,800	52,000?	0.62	0.60	3.3	?	West	23′ 8″	50′ 7″	4	6	72″	
8	" 27, 1894		191	139,000	80,800	52,000?	0.65	0.65	. . .	17.8	West	23′ 8″	50′ 7″	4	6	72″	
10	" 25, 1894		191	139,000	80,800	P. O.	0.64	0.64	. . .	21.2	West	23′ 8″	50′ 7″	4	6	72″	

TABLE III.—VERTICAL MOTION.

Freight Engines—Vandalia Bridge.

No. of Diagram.	Date.	Number of Engine.	Total Weight of Engine.	Weight of Tender.	Kind of Car Following Tender.	Max. Vertical Motion.	Average Vert. Motion at Max. Point.	Percentage of Increase due to Vibration at Max. Point.	Approximate Speed in Miles per hour.	Direction.	Wheel Base of Engine.	Distance from Forward Pilot to Rear Tender Wheel.	No. of Pilot Wheels.	No. of Drivers.	Diameter of Drivers.	Maker.
41	April 27, 1894	H 33	65,000	44,000	Box	0.49	0.49	. . . .	14.9	West	21′ 9″	. . . .	4	4	. .	
54	" 28, 1894	33	65,000	44,000	"	0.40	0.40	. .	16.1	West	21′ 9″	. . . .	4	4	. .	
35a	" 27, 1892	43	75,000	49,000	. . . .	0.44	0.42	4.8	18.8	West	22′ 7″	. . . .	2	6	. .	Baldwin
33a	" 26, 1892	160	68,000	50,000	. . . .	0.44	0.42	4.8	18.1	West	23′ 1″	. . . .	4	6	. .	"
39	" 27, 1894	H 170	65,000	44,000	Box	0.43	0.43	. . . .	6.1	East	21′ 9″	. . . .	4	4	. .	"
29	" 26, 1894	170	65,000	44,000	"	0.44	0.42	4.8	14.5	West	21′ 9″	. . . .	4	4	. .	"
13	" 25, 1894	I 171	75,700	49,000	"	0.42	0.42	. . .	10.4	East	21′ 9″	. . .	2	6	. .	
45	" 27, 1894	171	75,700	49,000	"	0.50	0.50	. . . .	15.2	West	21′ 9″	. . . .	2	6	. .	
35	" 27, 1894	J 153	76,000	50,000	"	0.46	0.46	. . . .	11.0 ?	East	23′ 8″	45′ 11″	4	6	50″	Baldwin
32a	" 27, 1892	174	76,000	50,000	"	0.49	0.48	1.0	16.7	West	23′ 8″	45′ 11″	4	6	50″	"
36	" 27, 1894	174	76,000	50,000	"	0.34	0.34	. . . .	3.3	East	23′ 8″	45′ 11″	4	6	50″	"
34a	" 27, 1892	175	76,000	50,000	. . . .	0.48	0.46	4.3	9.8	East	23′ 8″	45′ 11″	4	6	50″	"
50	" 28, 1894	177	76,000	50,000	Box	0.48	0.48	. . . .	12.6	East	23′ 8″	45′ 11″	4	6	50″	"
22	" 26, 1894	K 269	105,000	74,300	Furniture	0.41	0.41	. . . .	9.3	East	. . . .	. . . .	.	.	. .	
28	" 26, 1894	267	105,000	74,300	Box	0.56	0.56	. . . .	12.0	West	. . .	. . . .	. .	.	. .	
18	" 25, 1894	268	105,000	74,300	Coal	0.52	0.52	. . . .	15.2	West	20′ 9½″	48′ 2½″	4	6	. .	
19	" 25, 1894	269	105,000	74,300	"	0.58	0.57	1.6	13.8	West	. . . .	. . .	. .	.	. .	

TABLE IV.—VERTICAL AND LATERAL MOTION.

Special Yard Engine No. 19.—Vandalia Bridge.

Number of Diagram.	Direction.	Speed in Miles per Hour.	Max. Amplitude of Lateral Motion.	Maximum Vertical Motion.	Average Vert. Motion at Max. Point.	Percentage of Increase due to Vibration at Max. Point.	Remarks.
2	East	11.6	0.135	0.29	0.285	2.0	Engine going ahead.
1	"	17.8	0.03	0.30	0.28	7.1	
6	"	21.9	0.10	0.33	0.30	10.0	
4	"	25.1	0.13	0.32	0.295	8.5	
5	"	34.6	0.24	0.31	0.29	7.0	
3	"	36.9	0.305	0.32	0.30	6.6	
8	"	19.1	0.14	0.32	0.30	6.6	Engine going ahead and brakes applied as soon as on bridge.
7	"	35.7	0.24	0.32	0.30	6.6	
10	West	18.5	.	0.51	0.305	1.6	Engine backing.
9	"	20.2	0.19	0.31	0.29	7.0	
11	"	29.1	0.17	0.32	0.29	10.0	
12	"	15.4	0.15	0.30	0.29	. .	Engine backing and brakes applied as soon as on bridge.
			Mean	0.313	0.294	6.4	

TABLE V.—VERTICAL AND LATERAL MOTIONS DUE TO CARS.

Passenger Trains.—Vandalia Bridge.

Reference Number.	Class of Engine.	Av. Vert. Def. due to Engine.	Max. Vert. Def. due to Train.	Min. Vert. Def. due to Train.	No. of Cars in Train.	Max. Lateral Motion.	Remarks. Vertical Motion due to Train.	Remarks. Lateral Motion due to Train and Engine.
31a	A	0.34	Uniformly decreasing.	Due to light and short train.	2	0.11	Smooth record.	Due to engine.
49	"	0.34			2	0.09	" "	" " "
20	"	0.31			2	0.07	" "	Fairly regular.
7	"	0.32			2	0.09	" "	Due to engine.
43	"	0.39			2	0.12	" "	Engine and train.
12	"	0.40			2	0.08	" "	" " "
25	"	0.39			2	0.09	" "	Fairly regular.
33	B	0.37	No record.	No record.	7	. . .	. . . .	Very small.
22a	"	0.40	0.22	0.22	6	0.14	Very uniform train.	Principally due to engine. A little from train.
21a	"	0.54	0.38	0.31	5	0.10	Last two cars Pullmans. Def. = 0.38.	Due to engine and rear cars.
25	"	0.50	0.38	0.30	5	0.10	Last two cars Pullmans. Def. = 0.38.	" " " "
47	C	0.33	Unif. dec'g.	Unif. dec'g.	2	Small	Smooth record.	
28a	"	0.38	"	"	2	0.15	. . . .	Due to engine, decreasing as train passed.
13a	"	0.35	0.20	0.20	5	0.08	Smooth record.	Principally due to engine.
26a	"	0.41	. . . . .	. . . .	2	. . .	" "	" " "
14a	"	0.41	0.21	0.20	5	0.09	" "	" " "
16	D	0.36	. . . .	. . . .	1	. . .	" "	Very slight.
5	"	0.32	. . . .	. . . .	2	. . .	" "	Small, irregular, and due to entire train.
14	"	0.36	. . . . . .	. . . .	2	0.14	" "	Due to entire train.
15a	"	0.40	. . . .	. . . .	2	0.15	" "	" " "
40	E	0.39	0.23	0.20	6	0.13	" "	Principally due to engine.
15	"	0.40	0.22	0.22	5	. . .	" "	Very small.
9	"	0.40	0.25	0.19	6	0.15	" "	Principally due to engine.

TABLE V.—VERTICAL AND LATERAL MOTIONS DUE TO CARS.—CONTINUED.

PASSENGER TRAINS.—VANDALIA BRIDGE.

Reference Number.	Class of Engine.	Av. Vert. Def. due to Engine.	Max. Vert. Def. due to Train.	Min. Vert. Def. due to Train.	No. of Cars in Train.	Max. Lateral Motion.	Remarks. Vertical Motion due to Train.	Remarks. Lateral Motion due to Train and Engine.
20a	E	0.38	0.21	0.19	6	0.10	Smooth record.	Principally due to engine.
27	"	0.39	0.21	0.21	5	0.10	" "	" " "
46	"	0.40	0.20	0.20	5	0.10	" "	" " "
24a	"	0.42	0.24	0.22	6	0.26	" "	" " "
32	"	0.48	0.31	0.31	8	0.14	" " Center missing.	" " " Irregular.
48	"	0.47	0.23	0.23	5	0.13	" "	" " "
34	"	0.46	0.23	0.23	5	0.12	" "	" " "
19a	"	0.50	0.31	0.29	4	0.14	" "	" " "
55	"	0.42	0.33	0.30	4	0.12	" "	
24a	"	0.51	0.36	0.33	4	0.16	" "	Principally due to engine, but produced by cars also.
52	F	0.43	. . . . .	. . . . . .	6	. . .	" "	Small.
23	"	0.47	0.29	0.25	6	0.17	" "	Principally due to engine.
23a	"	0.45	0.34	0.24	7	0.16	" "	" " "
18a	"	0.47	0.36	0.31	8	0.16	" "	Engine and rear cars.
42	"	0.54	0.33	0. 9	5	0.17	" "	Principally due to engine.
30	"	0.52	0.27	0.25	7	0.15	" "	Engine and rear cars.
11	"	0.54	0.35	0.33	4	0.14	" "	Principally due to engine.
51	G	0.54	0.35	0.28	7	0.25	" "	Very irregular and due to engine.
38	"	0.55	0.36	. . . . . .	7	0.13	" "	Due to engine and rear cars. Fairly regular.
8	"	0.53	0.36	. . . . .	7	0.19	" "	Due to engine.
21	"	0.56	0.37	0.28	7	0.16	" "	Engine and rear cars.
24	"	0.60	0.23	0.19	9	0.18	" "	" " "
8	"	0.65	. . . . . .	. . . . . .	8	0.23	. . . .	Due to engine.
10	"	0.62	. . . . . .	. . . . . .	8	0.13	. . . .	" "

TABLE VI.—VERTICAL AND LATERAL MOTIONS DUE TO CARS.

Freight Trains.—Vandalia Bridge.

Reference Number.	Number of Engine.	Av. Vert. Def. due to Engine.	Max. Vert. Def. due to Cars.	Min. Vert. Def. due to Cars.	Number of Cars.	Max. Lateral Motion.	Remarks. Vertical Motion—due to Train.	Remarks. Lateral Motion—due to Train and Engine.
41	33	0.49	. . .	. . .	20	0.16	Culm. vib. due to rear cars. Max. swing = 0.06.	Engine and rear cars of train.
54	33	0.40	. . .	. . .	32	0.10	Culm. vib. 13th, 19th and 30th seconds. Swing about 0.06.	Engine and at 19th second.
35a	43	0.42	0.48	0.32	26	0.12	Ind. of culm. vib. near head of train. Record rough throughout.	Engine record irregular. Train record missing.
33a	160	0.42	0.40	0.25	23	0.16	Culm. vib. due to cars, but not at regular intervals. Max. swing about 0.06.	Irregular. Due to engine and train.
39	170	0.43	0.40	0.17	21	Small	Trace of vibration between 7th and 16th cars (loaded).	Evident between 7th and 16th cars.
29	170	0.42	0.40	. . .	18	0.11	Culm. vib. due to 7th car. Amplitude = 0.08. Period = 3 per second.	Engine and rear cars.
13	171	0.42	0.32	0.20	25	0.12	Vib. only evident by pen friction steps.	Engine and forward cars.
45	171	0.50	0.39	0.16	29	0.20	Very slight trace of vib. shown by pen friction.	Due to engine and center of train.
35	153	0.46	0.45	0.40	30	0.10	No vib., except as shown by pen friction.	More or less due to entire train. Culm.
32a	174	0.49	0.44	0.24	28	0.19	Some vib., but very irregular.	Max. for engine. Some for cars throughout.
36	174	0.41	0.48	0.40	29	Small	Smooth record.	Max. for tail cars.
3'a	175	0.46	0.36	0.15	21	0.12	1 case of culm. vib. near engine. Remainder of record smooth.	Due to engine and also some cars.
50	177	0.48	. . .	. . .		0.09		Culm. vib. at regular intervals.
22	269	0.41	0.28	0.16	23	0.07	No vib., except as indicated by pen friction steps.	Engine and cars. 2.2 vib per second for cars.
28	267	0.56	0.43	0.24	32	0.10	3 or 4 cases of culm. vib. at loaded cars. Max. def. due to tank cars.	Corresponding to vertical vibration.
18	268	0.52	. . .	.	35	0.13	Slightly culm. vib. 3 cases at irregular intervals.	Engine principally. No relation between V. and L. motion.
19	269	0.57	0.31	0.20	41	0.15	Some vib. near center of train due to refrigerator cars.	Engine and at center of train.

TABLE VII.—VERTICAL AND LATERAL MOTION DUE TO CARS.

FREIGHT AND PASSENGER CARS.—BIG 4 BRIDGE.

Reference Number.	Number of Engine.	Av. Vert. Def. at Max. Point due to Engine.	Max. Vert. Def. due to Cars.	Min. Vert. Def. due to Cars.	Number of Cars.	Max. Lateral Motion.	Remarks. Vertical Motion—due to Cars.	Remarks. Lateral Motion—due to Cars and Engine.
*69	196	0.54	0.27	0.20	5	0.17	No vibration. Steps due to pen friction.	Due to engine and rear cars.
*B	196	0.55	0.26	0.20	6	0.16	Culm. stepped. Due to pen friction.	Due to engine and cars.
*A	197	0.55	0.29	0.25	5	0.18	Pen friction and irregular vib. for engine.	Engine and last cars.
*66	197	0.57	0.30	0.25	5	0.20	Smooth record.	Engine principally. Slight for cars.
*70	116	0.36	. . .	. .	4	0.14	" "	Max. for engine. Little for cars.
*63	287	0.38	0.19	0.19	4	0.16	" "	" " " "
*75	379	0.43	. . .	. . .	4	0.13	" "	" " " "
*72	111	0.42	0.20	0.20	5	No	" " Excursion train.	No record.
64	299	0.42	0.20	0.15	8	0.16	Trace of vib. due to loaded coal car.	Max. for engine. Decreasing for cars.
76	300	0.39	0.14	0.14	7	0.17	Smooth record.	Max. for engine. Some due to cars.
62	450	0.58	0.36	0.18	30	0.26	" "	Engine and rear cars.
77	450	0.58	0.30	0.19	28	.	Trace of vibration.	No record for engine. For cars slight.
68	?	0.58	0.34	0.34	11	0.20	Smooth record.	Culm. vib. for rear cars.
73	408	0.58	0.36	0.25	13	0.18	" "	2 cases of culm. vib. near end of train.
60	435	0.59	0.26	0.19	26	0.17	" "	Engine and cars.
74	?	0.59	0.31	0.16	?	. . .	Slight trace of vib.	No record.
67	455	0.55	. . .	.	28	0.19	Smooth record.	Culm. for 5th car, a loaded coal car.
84	92	. . .	. . .	. .	2	0.0	Speed— 0.0 miles per hour.	Going—standing.
83	92	. . .	. . .	. . .	2	0.15	" 18.5 " "	" East.
81	92	. . .	. . .	. . .	2	0.14	" 20.1 " "	" East.
80	92	. . .	. .		2	0.16	" 19.3 " "	" West.
82	92	. . .	. . .	. .	2	0.18	" 19.9 " "	" West.

* Records for Passenger Trains.

TABLE VIII.—VERTICAL MOTION DUE TO PALACE CARS.

PULLMAN CARS.—VANDALIA BRIDGE.

Reference Number.	Name of Cars.	Weight of Car.	Length of Car over all.	Max. Vert. Def. when Cars were Sym. Placed about Center of Bridge.
25a	Almond	91,650	65′ 11″	. . . . . .
	Zida	. . . .	. . . .	0.38
23a	Almond	91,650	65′ 11″	. . . . . .
	Leixe	94,350	75′ 5″	0.34
24a	Clearmont	91,650	65′ 11″	. . . . . .
	Bala	95,030	75′ 5″	0.36
51	Clearmont	91,650	65′ 11″	. . .
	Bala	95,030	75′ 5″	0.35
8	Clearmont	91,650	65′ 11″	. . . . . .
	Colon	96,550	75′ 5″	0.36
42	Leicester	92,300	65′ 11″	. . . . .
	Gila	95,030	75′ 5″	0.33
21	Leicester	92,300	65′ 11″	. . . . . .
	Milo	95,030	75′ 5″	0.37
11	Piedmont	. . . . . .	. . . .	. . . .
	Ciny	99,760	75′ 5″	0.35
21a	Tremont	89,375	65′ 11″	0.38
	Cedro	95,550	75′ 5″	. . . . . .
18a	Tremont	89,375	65′ 11″	0.36
	Cedro	95 550	75′ 5″	. . . . . .
11	Tremont	89,375	65′ 11″	0.35
	Ciny	99,760	75′ 5″	. . . . .

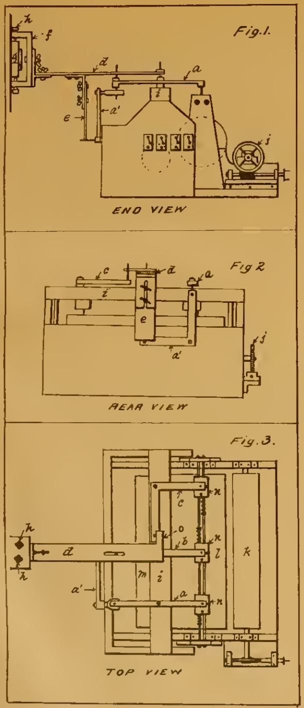
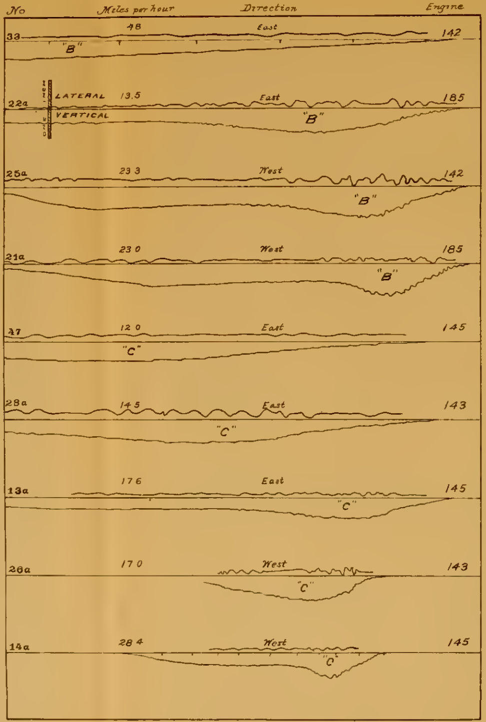
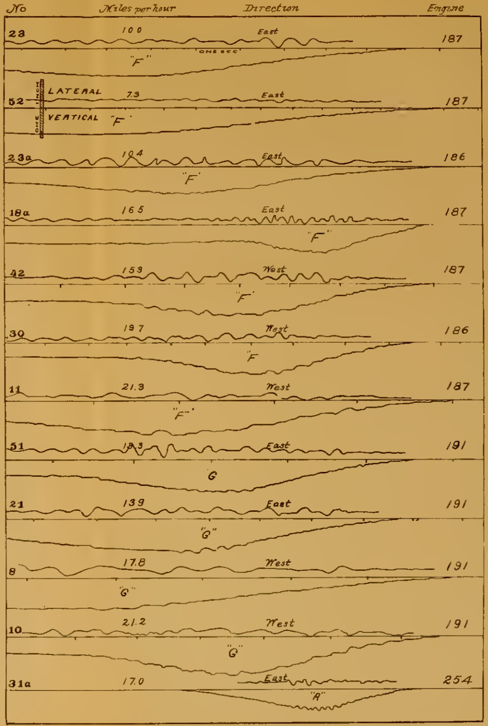
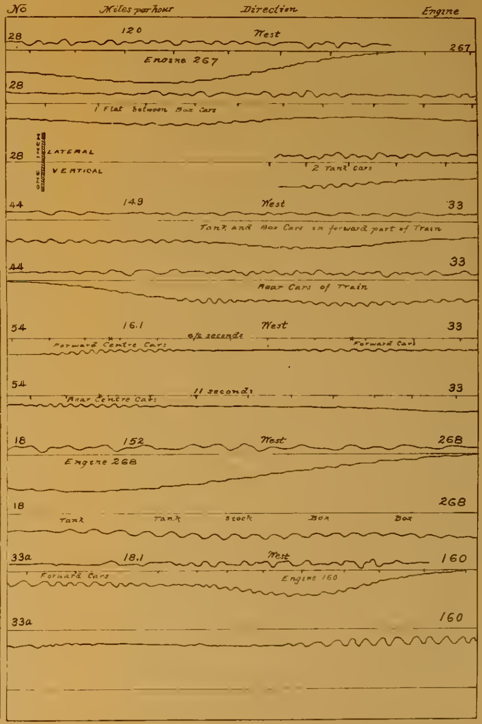


Fig. 1.
END VIEW
Fig 2
REAR VIEW
Fig. 3.
TOP VIEW







AN ENCASED STANDPIPE WITH SPECIAL PROVISIONS FOR WIND PRESSURE.

BY EDWARD FLAD, MEMBER OF THE ENGINEERS' CLUB OF ST. LOUIS.

[Read June 5, 1895.*]

STANDPIPES are constructed in connection with Water Works systems in order to relieve the pumps and pipe systems from excessive variations of pressure, or else to provide for storage of water.

If the object is merely to equalize the pressure, the standpipe need seldom be more than 5 or 6 feet in diameter, even for the larger cities, and it should, if possible, be placed in close proximity to the pumping station. Where storage of water is desired, the standpipe will usually vary from 10 to 30 feet in diameter, and it may be placed at any convenient location, proximity to the pumping station being of no particular advantage.

In the smaller cities standpipes are usually constructed for storage purposes, generally with a view to storing sufficient water for the consumption during the night hours, permitting of the banking of fires under the boilers, and reducing the operating expenses.

The Water Tower at St. Charles, Missouri, which is described herein, was constructed for storage purposes. The St. Charles Water Works were built by a private corporation under the franchise plan in 1881, and were at that time provided with an elevated tank located on the site of the present Water Tower, about 1½ miles from the pumping station.

The tank was of wood, 20 feet in diameter and 16 feet high, and was supported upon a brick substructure, 20 feet square and 40 feet high. After having served its purpose for the period of about eight years, the structure collapsed, and from that time until the completion of the present tower, the works have been operated on the direct pressure system.

It is generally supposed that the failure was due to the poor quality of the brick used in the substructure, and to their gradual disintegration, owing to the action of frost upon the brick when saturated with water which leaked or overflowed from the standpipe.

When the writer was intrusted with the design of a new storage tank, he had in mind a number of failures of similar structures, and determined to benefit as far as possible from the lesson taught by such failures. Out of twenty-five failures of standpipes referred to by Prof.

* Manuscript received June 22, 1895.—*Secretary, Ass'n of Eng. Socs.*

William D. Pence in his articles in the *Engineering News*, nine accidents were presumably due, at least in part, to the formation of ice, six being total failures; and six accidents were due to the effects of wind pressure, one of the six being a total failure.

A study of the failures which have been recorded leads to the conclusion that where no serious apparent fault in the design had occurred, when judged by the practice of leading engineers, the failures have been due to one or more of the following causes:

(1) Inferior material.

(2) Formation of ice.

(3) Lack of proper provision against wind pressure.

If proper attention is given to these three causes of failure there would seem to be no reason for doubting the ability of the engineer to design a standpipe which would be as safe as an elevated tank or any other engineering structure.

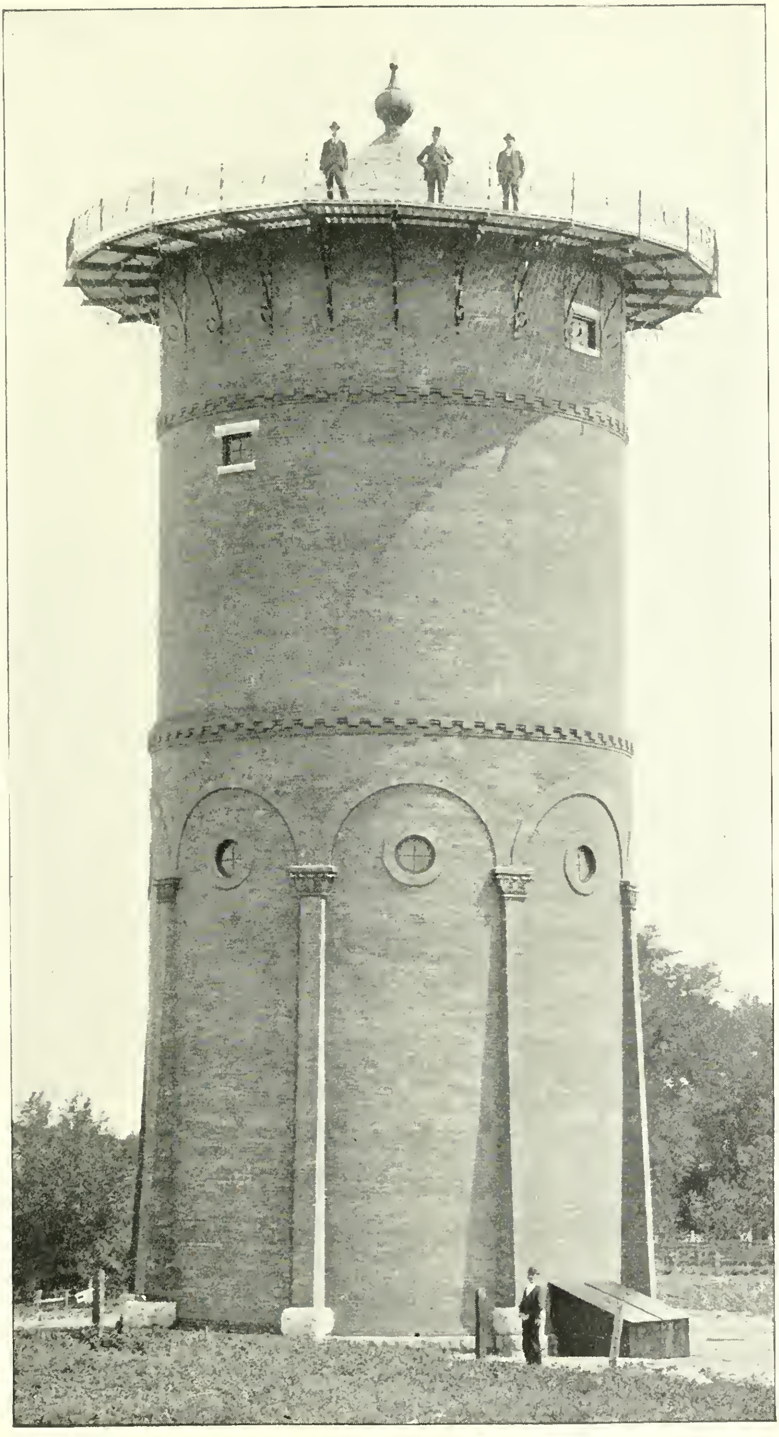
(1) In order to secure proper material it is of course only necessary to specify distinctly the quality of material required, and then to insist upon a rigid and careful inspection, and full compliance with the specifications.

(2) Where the standpipe is subject to extreme cold weather, a casing of wood, brick or other suitable material will usually offer sufficient protection against the formation of large amounts of ice, but if necessary suitable arrangements for heating can readily be introduced in connection with the casing.

(3) It has been customary to assume that a few stiffening angles and proper anchorage is sufficient to provide for wind pressure, the assumption being that the tank will hold its circular shape. For tanks of large diameter, however, further provision against wind pressure would seem to be desirable, in view of the many failures which have occurred, in order to avoid the collapsing of the upper sections or the vibration and swaying of the shell which is liable to occur during high winds, when the standpipe happens to be only partly filled with water. The provision for wind pressure adopted by the writer will be set forth in the description of the St. Charles Water Tower.

The drawings and photographs herewith show the design of the St. Charles Water Tower as constructed. The tank is 25 feet in diameter and 70 feet high, having a capacity of 250,000 gallons. It is encased in brickwork, a space of 2 feet being left between the tank and the inside of the brick casing. The foundation is built entirely of Louisville cement concrete faced with coursed rubble masonry. The roof is of metal and is covered with slate placed upon metal purlins.

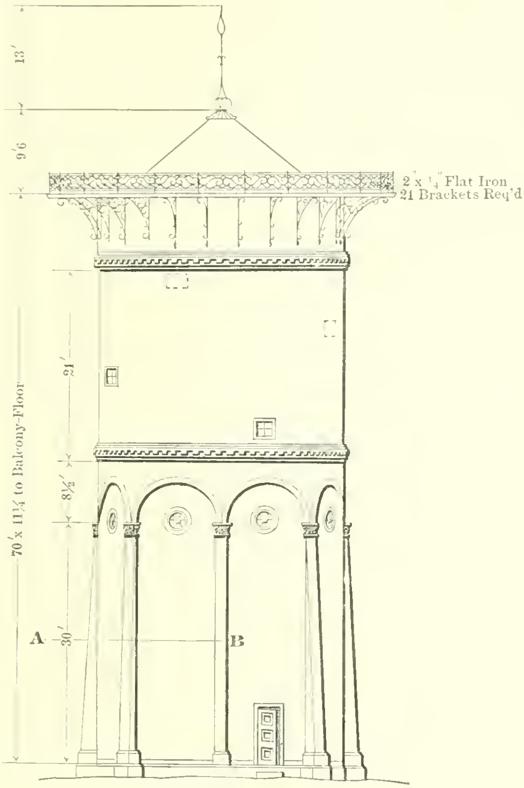
The plates of the shell are of soft open-hearth steel, having a tensile strength between 60,000 and 68,000 pounds, and an elongation of not less



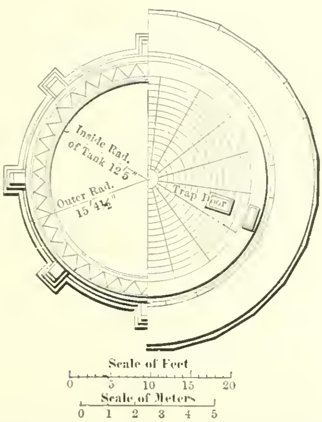
St. Charles Water Tower.

St. Charles Water Tower.
View showing Steel Tank and Circular Girders before the Construction of the Brick Casing was commenced.

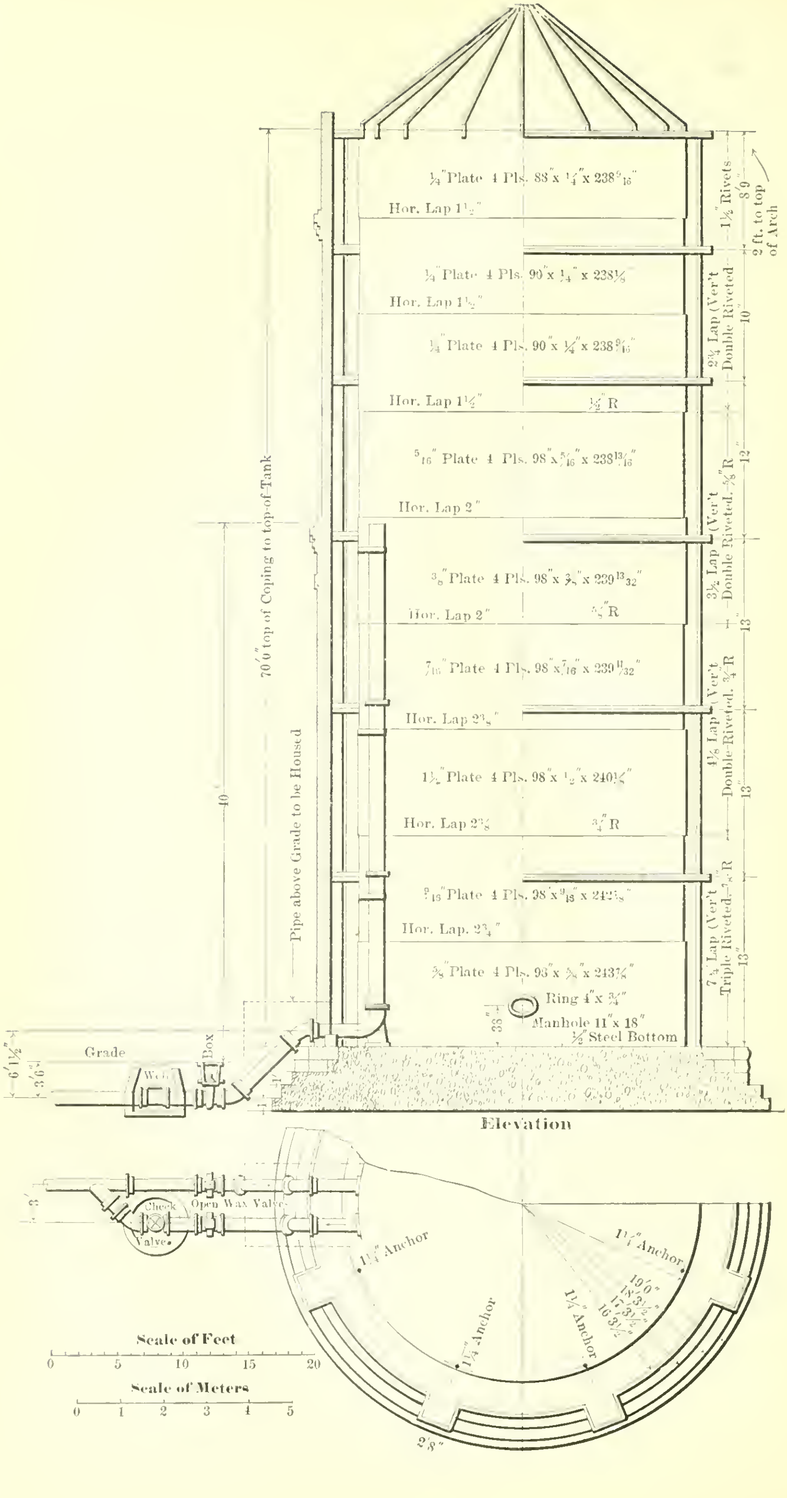
than 26 per cent. in 8 inches, and a reduction of area at fracture of not less than 50 per cent. Specimens were bent double and pressed flat without sign



Elevation



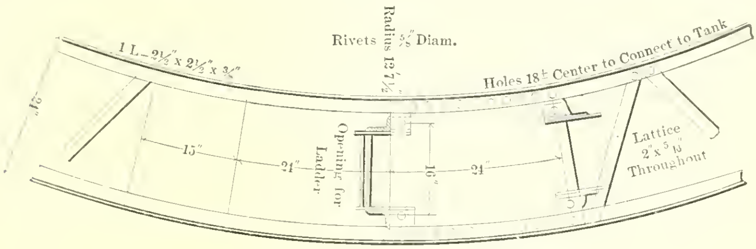
Half Section A B Plan of Roof and Balcony



Elevation
Scale of Feet
Scale of Meters
Pipe above Grade to be Housed
70'0" top of Coping to top of Tank
Grade
Box
Check Valve
Open Wax Valve
½" Steel Bottom
Manhole 11" x 18"

of fracture. There are nine rings in the shell, 4 plates to the ring. The plates of the six lower rings are 8′ 2″ wide and approximately 20 feet long. The sheets vary from $\frac{1}{4}''$ thick at the top to $\frac{5}{8}''$ thick at the bottom section.

The special provision for wind pressure, which it is supposed is used here for the first time, consists of a number of circular girders placed at intervals on the outside of the tank and riveted to same. These girders are made up of angles and lattice bars, one angle being used next to the tank and two angles for the outer flange of the girder.



¾ Inch 1 Foot

Plan of Circular Girder.

The brick casing rests against these girders. Wind pressure on the casing is therefore transmitted to the standpipe through the girders, and these latter hold the metal shell in its circular form and enable it to successfully resist the stress due to wind pressure. The girders therefore serve the double purpose of bracing the shell and casing.

Standpipes should be designed to successfully resist wind pressure when empty. The first effect of the wind is a tendency to collapse the shell, destroying the circular shape of the standpipe, and the upper thinner sections are of course the least able to resist such action. If sufficient rigidity is provided to prevent the collapsing of the shell, the standpipe will act as a cantilever, the leeward side being in compression. Adding such compressive stress to the compression produced at any section, by the weight of the metal above, we can readily calculate the total compression on the windward side.

There are no available data, however, which will enable us to determine how much compression is allowable upon a column 10 to 20 feet in diameter and 50 or 150 feet high, built of thin sheet metal.

The thickness of the metal in the shell required to resist collapsing, could be approximated by assuming a section contained between two horizontal planes a foot or more apart, and calculating the semi-circular strip on the windward side as an arch. Such calculations would show that the upper sections of our standpipes should be built with considerably thicker plates than has usually been customary.

By introducing horizontal circular girders at short intervals we provide an economical method for holding the tank circular and preventing the collapsing of the shell, on the windward side, and at the same time resolve the standpipe into a series of short columns, the compressive resistance of which, under the cantilever action, may be assumed to more closely approximate the crushing strength of the material.

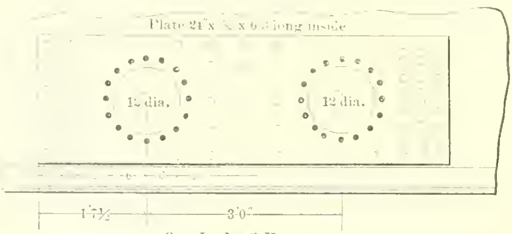
These circular girders on the standpipe hold a position similar to that occupied by the stiffeners on the web of a plate girder.

As the casing is braced laterally by the girders and metal shell, the brickwork is not required to be self-supporting, except so far as the dead load is concerned, and may therefore be made very light. The brickwork for the casing of the St. Charles standpipe was made only 13 inches thick for the lower 40 feet and 9 inches thick for the upper 30 feet. The pilasters and arches were introduced merely for architectural effect.

An inclined ladder is provided between the metal shell and casing, with a landing at each girder, so as to make the structure of easy and safe access for inspection and repairs.

There are two 12 inch water connections to the standpipe at the bottom, placed so as to be easily accessible. They enter the standpipe at the side and are housed in for protection against frost. Both of these lead to the same water main. The connection through which the water enters the standpipe passes up into the standpipe, discharging at an elevation of 40 feet above the base. The other connection terminates

Reinforce Plate at Pipe Connections

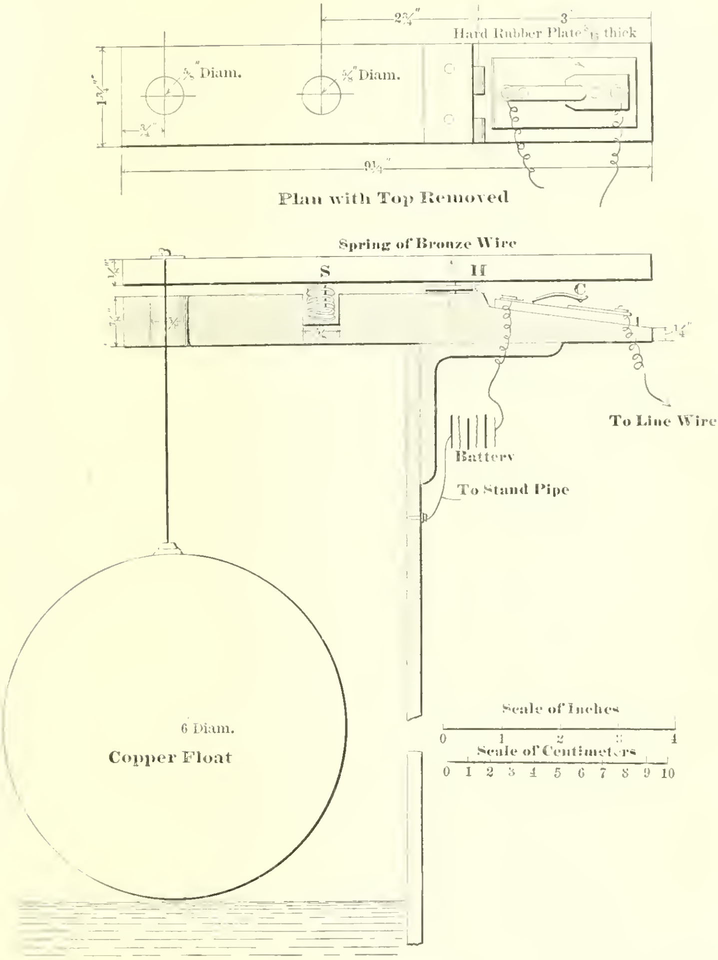


One Inch = 8 Feet

at the bottom of the standpipe, is provided with a check valve and serves as an outlet for the water when there is less than 40 feet of water in the standpipe. With this form of connection the full capacity of the tank is utilized for storage, and still a sufficient pressure is insured for fire purposes whenever the pumps are operated.

A high water alarm is provided, consisting of a float which actuates a lever and makes an electric contact, ringing an alarm bell at the pumping station whenever the water reaches within 3 feet of the top of

the tank. A single wire is used, the current being returned through the water main.



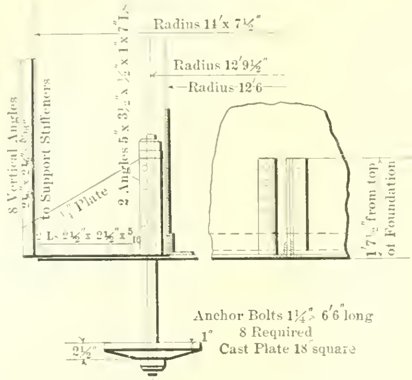
High Water Alarm.

The method used in erecting the shell is well shown in the photograph. A light scaffold was built inside of the tank, and a cage swung on the outside, the plates being raised with the aid of a jin-pole. A forge was placed on the cage and the rivets were driven from the inside.

After the bottom section was riveted together it was tested with water and made tight and was then lowered upon the concrete bed which had been previously leveled and smoothed with a trowel. Portland cement grouting was then introduced between the top of the foundation and the

bottom of the tank, 17-1¼″ holes having been provided in the bottom for this purpose. These holes were afterwards fitted with screw plugs.

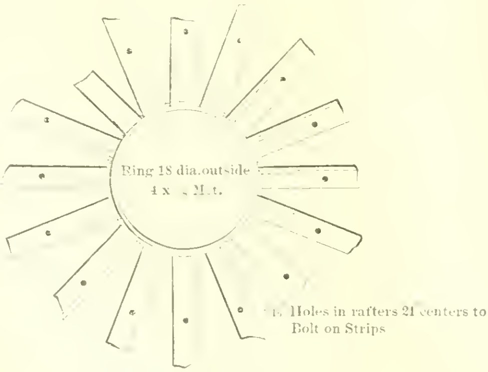
Anchorage Connections



The sheets of the bottom were lap-welded and the rivet heads were not countersunk.

After the iron work was completed the brick casing was erected with the aid of exterior scaffold.

The foundation rests on good stiff clay, the maximum pressure on which is about 3,700 pounds per square foot, which obtains when the tank is full of water.



One Inch = 3 Feet

The Chicago Bridge & Iron Co. were contractors for the iron work, which was completed in March 1895, water being admitted for the first time on the 23d of March.

The cost of the tower was as follows:—

Steel Standpipe, including girders and iron work . . .	$4,450 00
Brick Casing	2,807 00
Foundations	677 63
Total Cost	$7,934 63

SOME FACTS CONCERNING DRAWING FOR ENGINEERS.

By Frank Aborn, Member of the Civil Engineers' Club of Cleveland.

[Read June 11, 1894.*]

Since accepting the invitation of your committee to read a paper on drawing, the idea has continued to grow upon me that I was "carrying coal to Newcastle." Skill in drawing is a prime factor in the engineer's equipment. It is in hourly requisition in his daily work. How can I tell him anything new concerning it?

These are the conditions that have confronted me in preparing this paper; and, because of them, I have chosen to discuss the beginnings rather than the ends of acquisition, feeling that constant users of drawing will more readily understand and take more interest in discussing a few facts concerning the process of learning than they might in anything I could say about its application.

In discussing this subject the great difficulty is to keep in sight the simple fact that drawing is purely a descriptive agent. This is the one fact, that, in this connection, should never be forgotten. Kept in view, profitable discussion is possible, and once finding lodgment in the learner's mind, the acquisition of skill in drawing is only slightly less certain and rapid than learning to walk or to talk.

Drawing is precisely analagous to verbal language, except in the scope of its application, but, within its own peculiar limits, it is much clearer and more concise. Drawings are only essays in lines, which have the advantage over written essays in that they require less time in execution and may be read at a glance even by the uninitiated. Drawing is the natural Volapük. Everything may be described in words; but certain classes of ideas, mostly those of form, may be more concisely as well as more completely expressed in lines. And to read verbal essays one must be familiar with the language in which they are written, while drawing may be read with the same facility regardless of nationality. These are important advantages, but the most important of all is the ease and rapidity with which drawing may be read. To realize how great this advantage is, it is only necessary to imagine oneself attempting to read the descriptions of two similar mechanical devices, one of which is in drawing and the other is in writing. Both are equally complete and exact; but what a difference in the time, strength and capability required to read and comprehend their respective meanings! The drawing may be read easily by most anyone, while to read the written description requires time, close attention, and, above all, a mental training of an unusually high order.

* Manuscript received June 26, 1895.—*Secretary, Ass'n of Eng. Socs.*

Looking at drawing from this standpoint, and regarding it as merely a means of expression, puts us on common ground; and now, if you will pardon me, I would like to remind you of something else that you are entirely familiar with, but which it is necessary to mention in order that I may put myself in complete touch with you: I refer to the application of drawing in practice. Let me call to your minds the part drawing plays in the development of any new engineering enterprise. First, there is the general conception of the way a given end is to be attained. Then comes a series of preliminary sketches, the chief function of which is to assist in crystallizing the thought. After this comes more precise drawing. Everything, at this point, is exactly placed. Relations of parts are determined, sizes are established and interferences are avoided. Nothing more can be done preparatory to actual construction except to lift the picture out of the working drawings, so far prepared, and by thus showing how the device will appear when completed, make it clear where changes may be made which will secure greater economy of space or improve the general appearance. The final set of drawings is now made, including as many illustrative, detail sketches as will reduce the chances for misunderstanding and the necessity for verbal explanation to a minimum.

Such procedures involve two kinds of drawing, one of which describes dimensions and the other expresses appearances. Both kinds of drawing are in constant requisition in all varieties of construction work. Final drawings of both kinds must be instrumental, otherwise they cannot be sufficiently exact. But preliminary sketching, the thought-requiring, thought-provoking and thought-developing drawing, is almost exclusively free-hand.

The well-rounded draughtsman, then, must have command of both. He must be able to describe form pictorially as well as in dimension and have the capacity to express himself promptly, clearly and concisely both instrumentally and free-hand. But such draughtsmen are rare. All can execute dimension drawings, while very few have full, ready command of pictorial expression.

In light of the fact that what are called mechanical draughtsmen are to be met with on every hand, while persons possessed of practical command of free-hand pictorial skill are rarely found, it would seem a hazardous statement to say that pictorial skill is the easier of attainment, or that it is primary to command of dimension drawing, but such are the facts. Free-hand, pictorial skill may be acquired in less time than any other form of drawing, and, being acquired, all other varieties of drawing are mastered with the least expenditure of time and effort. Indeed free-hand skill so prepares the way that, if mastered, orthographic projections, isometric, perspective and all the draughtsman's

arts are understood instantly they are presented. The reason for this, as well as the proof that it is so, will readily appear if inquiry is made into the cause of the present condition.

A very brief investigation will show that it is due to an illusion regarding pictorial drawing and the absence of illusion regarding dimension drawing. To comprehend the full force of this fact, to understand what a part it plays in hindering the acquisition of skill, and to appreciate how simple and straightforward both teaching and learning to draw will be, when illusion is dispelled, it will be only necessary to make some inquiry into how we see and determine what constitutes resemblance.

Seeing consists in recognizing the fact that similar optical sensations are derived from similar sources. One object is recognized to be a horse and another to be a man, because the optical sensation derived from each is similar to that we remember to have experienced before, and to have proven to have been derived from a horse or a man, as the case might be. So infallible is this rule, that all things are alike from which similar optical sensations are derived, that the thought of an exception has no natural excuse. But there is a very common exception to the rule, which is met in every picture that is seen. A picture is a picture of an object only when the optical sensation it gives rise to is similar to that to be derived from the object itself and there is nothing to suggest that there is any important difference between them. But there is a very radical difference, and failure to properly appreciate it is the prime cause of all the difficulty every one experiences in learning to draw. It causes effort to draw to be invariably misdirected. It insures, that, for a longer or shorter time, at the outset of learning, in each individual case, every thought, every observation and every act shall be from a wrong point of view and on entirely mistaken premises. And this, too, in the most unshakable confidence in the correctness of both, but more or less distrust of personal capability to execute.

Before intelligent effort is possible, all this must be changed. The beginner in drawing must be brought to doubt everything but his own power to learn. He must be brought to question his understanding of conditions and requirements and to doubt the truth of his premises: but not to lose faith in himself or in his powers to gain.

Whether the individual is learning dimension or pictorial drawing, in one particular, at least, does not matter. Progress in the attainment of skill in any direction is entirely dependent upon the dawn of intelligence, and this is impossible in the presence of illusion. With regard to the hand, the pencil, or the paper, or the slate, in the elementary stages, all that is required is that they shall be capable of making and taking marks that can be easily seen. The prime factor is intelligence. When any one comprehends that all drawing is descriptive, in the same sense

that writing is descriptive, the drawing of lines will be undertaken with a clear understanding of what their true function is. As the understanding becomes more fully developed, discrimination will become more and more acute and the demand will be created for finer and finer execution, which will induce the successful effort to devise ways and means of meeting it.

Ruskin has somewhere said to this effect: "To learn to draw, one must come to look at things with his natural eyes." That is to say, he must look at things not as objects, but as surfaces, as the child looks at the sky at night, seeing all the stars as so many sparks on a plane, rather than as so many distinct bodies and systems at varying distances from us. Every one does this in dimension drawing, but no one does it in pictorial drawing. If they did, present conditions would be the reverse of what they are, and every one would learn pictorial drawing without difficulty, and learning dimension drawing would be child's play to what it is now. For when any one perceives the dissimilarity between picture and object he will intelligently approach all delineative problems because his point of view can never be mistaken nor his aim ever be wrong or uncertain.

Much has been and still is said about "talent" in drawing, meaning thereby that there is a certain quality of mind necessary to its attainment. Whether all people may become true artists need not be discussed here; but that peculiar "talent" is required in the acquisition of practical skill in pictorial drawing, such as would admit of its being used as freely and readily as writing, has not the slightest foundation in fact. That such skill is not common proves nothing. Learning to draw is a question of state of mind and not of quality. Practical command is within the reach of every one. It may be speedily acquired by whoever will assume and maintain the proper point of view. Whether any one attains to art is dependent upon conditions similar to those which maintain in literature. The great question in drawing, as in writing, is place. Is the line in the place to most effectively express the idea? is no less an important question than is the sequence of sentences in writing and speaking. This way of looking at it simplifies every phase of drawing. Nothing could be more straightforward, but, unfortunately, few things are so generally misapprehended. To see how deep-rooted this misapprehension is it is only necessary to observe how loose, baseless and sentimental most of the talk is that is used in this connection. Advocates of drawing have a good deal to say about art, for instance, which is as much out of place in this connection as it would be to talk about art in literature in connection with learning to read before the ability to express one's self intelligibly in words has been established. There is a good deal of generalization indulged in to the

effect that learning to draw induces the exercise of all the cardinal virtues. Mere sentimental gush, which is belied by the lives of most of those who should be its chief exponents, who, so far as I know, are no more cleanly, orderly or moral than other people. Such ceaseless exaggeration does no good, but actually harm. It tends to bring into disrepute what in truth is a most hard-headed, practical tool, not only as a means of expression, but as a means of developing a broader and better command of the intellectual faculties. Such effervescence tends to belittle the subject itself; but there is another class of expressions in common use that are at least unfortunate in that while they are not exactly false they are not wholly true, and, if not actually misleading, they do not contribute to dispelling illusions nor the evidence of misdirected effort. For example, lines are commonly regarded as comparable with letters, and for this reason instruction in drawing uniformly begins with practice in line-making in some form, however it may be disguised. This is a mistake. Drawing is a language, it is true, and it is impossible to have any just conception of it except from this standpoint. But the statement so often met with that drawing is a language of which the straight and curved line are the alphabet, is utterly incorrect and misleading, notwithstanding it is the view held by Dr. Harris, Commissioner of Education, and many others.

Drawing is a natural language, like speaking, and has no alphabet. Letters are mere arbitrary symbols, fixed in their form, while lines are variable. Not subject to caprice, however, but changing both in form and character with every modification of the point of view, precisely as the form and construction of sentences change under similar circumstances. Even the shortest line, a point, is a full sentence. It is in every way equivalent to "It is here." It expresses a fact of position as completely and more concisely than could be done in words. A line of more than one point expresses position, direction and distance. It is, at least, the equivalent of "This is the direction and distance between two points." Whether a line is rough or smooth, straight or crooked, is secondary. Whether it is most effectively placed is primary. There are also other forms of expression in common use in this connection, which, though they do not actually befog the mind, do not contribute to clarifying the intellectual atmosphere.

It is common to say that an object is drawn, meaning that it is delineated. But such a statement cannot be true. An object can no more be drawn than it can be written. As an object may be written about, so it may be drawn about. A picture may be drawn, but not an object. A picture can have but two dimensions, while every object must have three. It is also common to say that the object is looked at when it is drawn, but this, too, is incorrect. In drawing, the intelligently

directed eye does not direct itself *at* the object, but *beyond* or *by* it, a fact which will be further explained farther on.

As I understand it, the engineer values drawing exactly in proportion as he is able to use it supplementary to verbal language. He desires the ability first to express himself in it as freely as he does in writing. He cares no more what effect the general possession of such skill among the masses might have upon art than he does what effect a new invention is going to have on an older one. What he desires is command of a tool which will enable him to accomplish more with less effort. To this end, the established systems of teaching drawing have been proven totally inadequate. Their whole reliance is based upon doing or executing a certain number of prescribed things with a certain degree of precision. They are ponderous, stupid and inefficient.

That the average individual does not gain possession of this tool language by himself is plain. And that the teacher can only help him to do so in proportion as he himself understands the requirements of the case, and knows how to meet them, goes without saying. It is manifestly not enough that the individual goes through a given series of executions, for if it were, every grammar-school pupil would be able to draw anything. The simple use of drawing, as is now so general, with a view to securing greater efficiency by means of correlation, is also unproductive of proper understanding and is unproductive in the very large majority of cases Drawing from objects most carefully selected, and with the assistance of criticisms from those who know, may fail for reasons which I shall explain farther on. A knowledge of perspective is everywhere proven to be inadequate. If it were not thus, every student of descriptive geometry would be an all-round draughtsman, and they are not. Modeling in clay will not develop a command of pictorial drawing; if it would, every modeler and carver would be a draughtsman in the best sense, and they are not.

So much is preliminary; but it has been necessary in order that common ground between us may be assured. The real facts which I most desire to make clear are so infinitesimal and yet so perfectly plain to be seen, that they are uniformly overlooked, as I overlooked them for many years, expecting to find something deep, intricate, or obscure. But so plain and simple are the steps in learning to draw that the only marvel is that they need even to be suggested. Yet so long a chase have they led me and so difficult do I find it to make myself understood that I have trespassed on both your time and your patience. But the rest is soon told.

Allow me at this point to remind you of a few simple, commonplace facts. The first of these facts is that nothing can be seen except it hide something else from view. For example, I could not be seen by you now

were it not for the fact that I prevent your seeing some of the wall behind me. If the button on my coat did not hide some of the coat it could not itself be seen. If my hand did not hide a part of my body it would not be visible. And if my thumb did not prevent some of my hand being seen by you it could not be known that I had a thumb.

If then you were to make a picture of me, at this time, you would not draw me but my silhouette. If you were to make a picture of the button on my coat you would not draw the button, but the shape that the button hides. To one this hidden shape would be almost if not quite a straight line, to another it would be an ellipse, while to still another it would be a circle, and no one would look *at* the button while describing it, but he would look *beyond* it. Likewise with my hand, in no case would it be drawn, but the shape that it hides; or, speaking more exactly, the base of the pyramid of rays of light reflected from the hand to the eye would be drawn.

It will be seen from this that the ability to draw is not dependent upon the possession of any modicum of knowledge, neither is it dependent upon any peculiar quality of brain, but it does depend upon the absence of all illusion and a clear, unclouded intelligence regarding requirements. In other words, learning to draw is dependent upon a state of mind. To get into this state of mind is the business of the learner, and to induce this state of mind is the duty of the teacher. It is not enough that this or that has been done, it is not enough to draw fine lines, make fine executions, nor to draw from the antique.

The acquisition of skill in drawing is precisely similar to all other processes of development. It is not unlike the development of an invention. It consists, first, in a struggle for comprehension. Nothing is polished or finished until it is fitted, nothing is fitted until it is located, and manufacture is not begun until everything else is done. Development and manufacture cannot be successfully carried on simultaneously in anything, particularly anything educational. Every drawing must be made for one of two purposes, it must be a means or a product or end. In proportion as it seeks to be both it fails in both. If a drawing is a means, it can have no value, if it is an end it is much for itself, or a part of something else, and has more or less value according to the condition of the market. Learning to draw is an educational or developing process, the drawing of every line is done with a view to an end which lies outide of the doing or the line. In the beginning stages it is a means of correcting the understanding of requirements, after that it becomes a means of improving the power of discrimination. Then it becomes a means of expressing ideas, and, finally, it is the means of emotional expression and culture. It is a perfectly direct highway, unmistakable as a turnpike when once seen, passing without deviation, from intelligence

to culture through the conscious exercise of power. Whether the aim or destination is power or culture, the ways and means are in nowise affected.

The first step in development is to dispel all allusion regarding the relation between picture and object. This is best done objectively, but it is a delicate operation. If it is done right the result is favorable, quiet and certain. I will not burden you with the details of a complete course as I would lay it out for children, but will suppose, if I may, that there were some of you who cannot draw pictorially, and that I wished to illustrate how you might be taught. I would choose some object that could be so placed that in some one respect there would be a marked case of foreshortening, bringing out the strongest possible contrast between the pictorial and actual relations of parts.

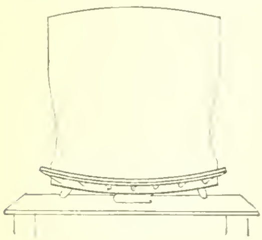


Fig. 1.

I might select a chair for the purpose, and place it where its back would be foreshortened, as shown in Fig. 1. The class being now instructed to draw something that would show how they see the chair from where they sit, the result would no doubt resemble Fig. 2. Each of these results would be an exact exposition of the state of mind regarding the requirements of drawing, of the individual who made it. And what the effect of making it may be depends upon how I, as the instructor, proceed. What I do, in this capacity, depends upon the purpose I have in view. If I desire an immediate result I criticise the execution and the condition and quality of the pencil and paper, as well as point out errors and suggest errors in the drawing. Learning to draw under such management will be exceedingly slow and very doubtful. If I wish to concentrate my forces, and bring out errors with effect, the number of different ways I might proceed depends upon my ingenuity.

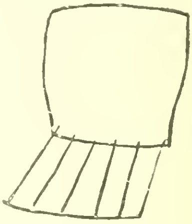


Fig. 2.

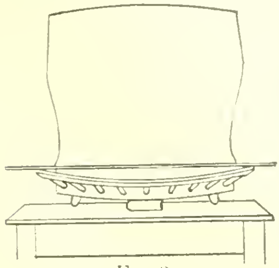


Fig. 3.

For instance, by laying a stick across the rail of the back of the chair, as shown in Fig. 3, and by thus calling attention to where it is seen, and making it clear that, because the stick is seen and should be drawn higher in the picture than the back of the chair-seat, makes it clear that the rail, itself, since it touches the stick should also be drawn higher than the back edge of the chair-seat. Or, the same end might be secured in a simpler way. It might be done by simply calling attention to the fact

that the spindles of the chair-back are seen below the rail while they have been described above it. It may be brought out, in this connection, that describing the spindles above rather than below the rail is a falsehood. But, however, it is done it is ineffective or rather insufficient. Objects may be described over and over again and there will remain a large number, if not a majority, who do not learn. If, however, my purpose is to come at the cause of error and make that clear, rather than to point out the error, I shall make use of the back-ground. In every case I shall ask him to show me what the misplaced part hides. This he will do instantly. He will then comprehend where it should have been placed and why he failed to place these. In the present case I should ask the pupil if he could see the whole of the top of the chair-seat. If he answered yes I should, by making chalk marks on the chair-seat that I would know to be hidden to him, bring him to see that he could not see the whole of it and what prevented. There is no one so dull of comprehension that he cannot comprehend this, and very presently any one will come to understand the cause of their errors and avoid them. They are, then, intelligent. But intelligence is not enough. Skill is what is wanted. The ability to describe what can be seen is only the entering wedge. Engineers do not draw for fun. It is business with them and business rarely if ever requires them to describe what is present and visible. Such things are their own best exponent, drawing about them is not called for. What the engineer requires is power, which is the ability to describe absent objects or things that exist only in his imagination.

As soon, then, as intelligence is established, the exercise of the imaginative faculties should be taken up and vigorously pursued; beginning with the description of present objects from imaginary and inaccessible points of view and proceeding to pure invention.

But approximate work will not do. The discriminating sense must now be developed. The subject-matter in this case must be such as will demand the closest observation of relations, at the same time it must have, in itself, such an interest for the student as to enlist and hold his constant and undivided endeavor. Such a subject for study is the human head from life. Nothing else is so fascinating, so exciting, so instructive or more cultivating.

In all work, when rightly aimed, there is a natural constantly increasing demand for better execution. At the proper time, in the place and in the proper degree, technique will have its proper attention. But it cannot economically precede intelligence nor take the place of power.

THE LIBRARY.

It is proposed to notice briefly, in this department of the JOURNAL, such engineering publications as may find their way to our shelves.

Publishers are requested, in sending works for review, to state the prices of same.

Motive Powers AND THEIR PRACTICAL SELECTION. By Reginal Bolton. London and New York: Longmans, Green & Co. 257 pages.

The author has set himself the task of compiling in convenient form the data and formulæ which bear upon the selection of a motive power suited to the conditions of any particular case, and of arranging these in convenient shape for reference by engineers or ready comprehension by the non-technical. The work has been well done, and the only wonder is that it has not been done before, as it must prove of great value and economy to those contemplating the use of power.

The author first discusses the primary considerations as to the various sources of motive power and their availability, and then devotes separate chapters to manual, animal, wind, water and steam power, as well as to electricity and to gas engines. For each of these rules are given, which permit of calculating the size of machine required, the cost of working and the relative economy under various conditions. There are a number of valuable tables, showing how the comparisons may be made, and the results are given both in pounds sterling and in dollars.

NOTE.—This notice is contributed by the Western Society of Engineers, to which the author has kindly sent a copy of his book.

// Association of Engineering Societies.

Vol. XIV. JANUARY, 1895. No. 1.

PROCEEDINGS.

Engineers' Club of St. Louis.

409th Meeting, January 2, 1895.—President Russell called the Club to order at 8.05 p.m., at 1600 Lucas Place. Twenty-two members and five visitors were present.

The minutes of the 407th and 408th meetings were read and approved. The Executive Committee reported the doings of its 174th, 175th and 177th meetings, announcing that the dues for 1895 had been fixed at $8 for resident members and $5 for non-residents. The Committee had approved the applications for membership of F. E. Bausch, S. E. Johannessen, W. A. Layman and A. W. Morrell, and these gentlemen were then ballotted for and elected. An application for membership was announced from Mr. William H. Moore, surveyor in the office of the street commissioner.

Col. E. D. Meier then read a paper on "Chimneys and Chimney Drafts." The paper had been printed, and copies were given to those present. The subject was considered with special reference to modern boiler practice and American coals. Computations of stack capacity usually assume the chimney gases to be of the same specific gravity as air. This assumption is erroneous, for, when combustion is complete, the gases are really a mixture of carbonic acid gas, nitrogen, and steam; the proportions varying with different coals. As these require different amounts of air, the varying weights of the gases of combustion cause a difference in the draft power of the same chimney. It is rare that just the proper amount of air is admitted, and there is a loss when the amount is too little or too great. Very often there is a surplus, reaching sometimes as high as 100 per cent. Tables were presented, showing these facts clearly for five well-known coals: Anthracite, New River, Youghiogheny, Mount Olive, and Collinsville. Computations were made, showing how the capacity of a chimney could be increased much beyond the normal by raising the temperature of the gases, the result always being accompanied by a corresponding loss in efficiency. It was shown that the same capacity could be obtained without loss of efficiency by increasing the height of the chimney. A table was given, showing the changes effected in the capacity of a given chimney by varying the temperatures of the gases; also the change of height necessary while maintaining a constant temperature. Another table showed the effect of different coals on the velocity of the gases, and on the areas of chimneys, the velocity being kept constant. The chimney formulæ of Smith, Kent, and Gale, and the experi-

ments of de Kinder, were discussed. A table was given, showing appropriate heights and areas of chimneys for powers from 75 to 3100 horse-power, assuming seven pounds of water evaporation per pound of coal, and five pounds of coal per horse-power per hour. The effect of the length of the flue leading to the chimney was also discussed. It was shown that where a number of boilers are to be connected to the same stack, its dimensions can be reduced proportionately (as compared with the first few boilers), as they would never all be fired at the same time.

The paper was discussed by Messrs. Hermann, Ockerson, Bryan, Holman, and Kinealy. It was shown that large chimneys almost always overrun their capacity as computed by the best formulæ. It was believed that the table presented by Col. Meier, while justifying the working of chimneys to larger capacities than heretofore deemed advisable, was still conservative, and that in emergencies the chimneys could be worked much beyond the ratings given.

Mr. Russell explained an ingenious method which had recently been resorted to at the inlet tower of the new water works at the Chain of Rocks for cutting off the timber of the old coffer-dam under water. Adjourned.

WILLIAM H. BRYAN, *Secretary.*

410TH MEETING, JANUARY 16, 1895.—The Club was called to order at 8.10 P.M., by Vice-President Ockerson, at 1600 Lucas Place. Twenty-one members and seven visitors present. The minutes of the 409th meeting were read and approved. The Executive Committee reported the doings of its 178th, 179th and 180th meetings, announcing the resignations of J. C. Simpson and D. C. Humphreys, and approving the application for membership of W. H. Moore. The Committee submitted the following program of papers and addresses for the year 1895:

January 2d—Chimney Draft, E. D. Meier.

January 16th—River Surveys by the Transit and Stadia, J. L. Van Ornum.

February 6th—Discussion of B. L. Crosby's paper on the St. Louis Extension of the St. L., K. & N. W. R. R. A System of Removing Organisms from Liquids. J. H. Curtis.

February 20th—The Mechanics of Soaring Flight (a translation), E. D. Meier.

March 6th—Timber Physics, J. B. Johnson.

March 20th—European Engineering Schools, W. S. Chaplin.

April 3d—Methods of Determining the Heating Power of Coals, J. H. Kinealy.

April 17th—Vitrified Brick for Street Paving, H. A. Wheeler.

May 1st—The Design of the Train House of the New Union Station at St. Louis, Geo. H. Pegram.

May 15th—An Experimental Investigation of the Three Moment Theorum, M. A. Howe.

June 5th—Water Towers at Laredo, Tex., and St. Charles, Mo., Edw. Flad.

September 18th—Maintenance of Bridges, C. Gayler.

October 2d—The Continuous Rail in Street Railway Service, R. McCulloch.

October 16th—Sewerage of Indianapolis, C. C. Brown.

November 6th—Chimneys and Chimney Draft, W. E. Worthen.

November 20th—Report of Committee on Smoke Prevention.

December 4th—Annual Meeting.

December 18th—Installation of Officers Address of Retiring President.

The Executive Committee recommended to the Club that Mr. Henry Flad be elected an honorary member.

On balloting, Mr. Flad was unanimously elected an honorary member and Mr. W. H. Moore a member.

The Secretary read a communication from Col. E. D. Meier, Secretary of the American Boiler Manufacturers' Association, asking the co-operation of the Club in a movement to secure legislative enactment in the direction of State Boiler inspection and the licensing of engineers. On vote, it was ordered that the Chair

appoint a committee of three to consider the matter, and to meet a committee of the American Boiler Manufacturers' Association, the Committee to have no authority to bind the Club in any way, but to report to the Club the result of its conferences and conclusions. The Chair appointed on this committee Messrs. Holman, Bryan and Perkins.

Mr. J. L. Van Ornum, of the Western Society of Engineers, then read a paper on "River Surveys by the Transit and Stadia," describing a method of surveying the smaller navigable streams by the use of the stadia alone for all topographical work, as well as for the location of soundings, thus dispensing with both the triangulation system and the angular methods of locating soundings.

The plan was particularly recommended where speed, low first cost and reasonable accuracy were desired, rather than extreme precision. The discussion was quite full, and was participated in by Messrs. Moore, Bouton, Ockerson, Butler, Jolley and Crosby. Adjourned.

WILLIAM H. BRYAN, *Secretary.*

Civil Engineers' Society of St. Paul.

ST. PAUL, MINN., JANUARY 7, 1895.—The twelfth annual meeting of the Civil Engineers' Society of St. Paul was held at 8.30 P.M. Fifteen members and one visitor were present. Vice-President Estabrook presided. The minutes of the previous meeting were read and approved. The Librarian reported verbally on a method of securing back numbers of the *Transactions of the American Society of Civil Engineers*, and the JOURNAL OF THE ASSOCIATION OF ENGINEERING SOCIETIES. The report was accepted. Mr. Morris gave the Society an outline of recent work of the Board of Managers of the Association of Engineering Societies. The discussion of the Minnesota State Survey and other matters incidental thereto was entered into at considerable length, and the committee thereon was granted another month's time to make a report. The gift of various back numbers of the *Railroad Gazette* and other periodicals was accepted from the "Omaha" Railway Company and ordered bound. The following annual reports were read and accepted:

REPORT OF THE SECRETARY.

ST. PAUL, MINN., January 7, 1894.

To the President of the Civil Engineers' Society of St. Paul.

SIR:—In accordance with the usual custom I present the Society statistics for 1894.

Eight regular meetings have been held, with an average attendance of thirteen members and three visitors. The subjects which were discussed for the entertainment of the Society are given below, with dates. Most of them were informally presented, but the papers of Mr. Johnson, Mr. Claussen and Mr. Woodman were carefully prepared. Mr. Woodman's paper on Transition Curves will shortly appear in the JOURNAL OF THE ASSOCIATION OF ENGINEERING SOCIETIES.

February 5th, "Construction of Dam at St. Anthony Falls," by Mr. C. A. Hunt. "Failure of a Portion of Westminister Street Tunnel," by Mr. K. E. Hilgard. "Diagram for Weir Measurements," by Mr. A. Münster.

March 5th, "Coal Docks and Coal Handling Plants," by Mr. C. J. A. Morris.

April 2d, "The Supply of Water Obtained from Government Reservoirs in Minnesota," by Mr. Archibald Johnson.

May 7th, "Requirements of a Municipal Electric Light Plant Installation," by Mr. O. L. Claussen.

October 1st, "Transition Curves," by Mr. Edwin E. Woodman.

November 5th, "The Minnesota Geological and Topographical Survey," by Prof. W. R. Hoag, of Minneapolis.

December 3d, "Riparian Ownership of Lands Bordering on Lakes and Rivers," by Mr. J. H. Armstrong.

On October 20th, ten members of the Society attended a joint excursion to Sault Ste. Marie, arranged by President Cappelen of the Engineers' Club of Minneapolis. Two days were spent in examining the new locks on both sides of the river and other improvements in the vicinity.

MEMBERSHIP STATEMENT.

January 1, 1894	54	Resident members	39
Increase in membership	3	Non-resident members	18
Present Membership	57		57

Respectfully submitted,

C. L. ANNAN, *Secretary.*

REPORT OF THE TREASURER.

President Civil Engineers' Society of St. Paul.

SIR:—I submit herewith my report as Treasurer of the Society for the year ending December 31, 1894.

RECEIPTS.

Cash on hand, January 1, 1894	$ 1 74
Collections during year	239 27
	$241 01

DISBURSEMENTS.

Stationery and miscelleaneous accounts	$ 14 10
Dinner at Commercial Club	17 00
Room rent	10 00
Library: Subscription to periodicals, etc.	78 96
Assessments, Association Engineering Societies	77 65
Cash on hand	43 30
	$241 01

Respectfully submitted,

A. O. POWELL, *Treasurer.*

REPORT OF THE LIBRARIAN.

To the President of the Civil Engineers' Society of St. Paul.

SIR:—The total number of volumes in the library at the end of the year 1894 was 352, including engineering periodicals for the past year. Of this number, 255 are bound volumes and 97 unbound, including the *Annales des Ponts et Chaussées* for the years 1891, 1892, 1893 and 1894, to the number of 48 volumes. The Society now subscribes for, or receives free, the following engineering periodicals: *Transactions of the American Society of Civil Engineers; Transactions of the American Society of Mechanical Engineers;* JOURNAL OF THE ASSOCIATION OF ENGINEERING SOCIE-

TIES; *Journal of the New England Water Works Association; Engineering; Engineering News; Engineering Record; Proceedings of the Western Railway Club; Engineering and Mining Journal; Annales des Ponts et Chaussées.*

Respectfully,

A. MÜNSTER, *Librarian.*

Officers for the coming year were elected as follows:

President, H. E. STEVENS.

Vice-President, K. E. HILGARD,

Secretary, C. L. ANNAN.

Treasurer, A. O. POWELL.

Librarian, A. MÜNSTER.

Representative on Board of Managers for the Association of Engineering Societies, EDWIN E. WOODMAN.

A vote of appreciative recognition of past services was given to Mr. Morris and other retiring officers. President Stevens appointed Mr. Rundlett auditor of accounts for 1894, and named Mr. Woodman, Mr. Powell and Mr. Armstrong as members of the Examining Board. The Treasurer was authorized to make the usual arrangements for the care of the library.

C. L. ANNAN, *Secretary.*

Civil Engineers' Club of Cleveland.

ROOMS OF THE ELECTRIC CLUB OF CLEVELAND, O., JANUARY 8, 1895.—The meeting was called to order at 7.55 P.M. by the President. Thirty-five members and visitors were present. The minutes of the meeting of December 11, 1894, were read and approved. The report of the Executive Board was read and approved.

Under the head of miscellaneous business, President Swasey brought up the question of returning to our former quarters in Case Library, stating that Mr. Rawson and he had learned that it was expected by the library people that we do so. He also stated that he had written a letter to the Librarian, asking when we might expect to resume our pleasant relationship, and had received a reply to the effect that the library would be ready on or before the 20th of January. On the request of the President, Mr. Rawson stated that, while acting not officially, he had accidentally discovered that we were expected to return, and at the former terms, that he had brought the matter to the attention of the President, and that the above result had been reached by further inquiry. Mr. Porter stated that he had learned that books and papers could be consulted in about ten days. Mr. Searles brought up the matter of entrance, and stated that he understood that entrance could now be gained to quarters only through the library proper. He suggested that inquiries be made as to whether we were likely to be embarrassed as to hours of meeting or of adjournment. Remarks were also offered by Messrs. Warner, Herman and Reid. Mr. Rawson moved that the matter be referred to the Executive Board with power to act. Seconded by Mr. Searles, and passed.

Mr. Searles submitted amendments to the Constitution, as follows:

CIVIL ENGINEERS' CLUB OF CLEVELAND.

Amendments to Constitution, proposed January 8, 1895.

ARTICLE 5.—DUES.

Section 1.—Strike out " Five " and substitute "Ten."
Section 2.—Strike out " Eight " and substitute " Ten."
Strike out " Six " and substitute " Eight."
Strike out " Four " and substitute " Five."

ARTICLE 9.—AMENDMENTS.

Section 2.—Strike out all after the word " which," and insert " shall go into effect on the first day of March next following the date of adoption."

We, the undersigned active members of the Civil Engineers' Club of Cleveland, present the above Amendments, and move their adoption.

(Signed),
JAMES RITCHIE,
WM. H. SEARLES,
N. P. BOWLER,
W. R. WARNER.

Mr. Searles moved to amend Amendments by considering the three various sections separately. Seconded and passed.

Mr. Porter moved that we proceed to ballot for the Nominating Committee, and the nominations were placed upon the blackboard. The President appointed Messrs. Palmer and Brown tellers, who announced the result as follows: Nominating Committee, Messrs. Porter, Warner, Searles, Bartol and Gobeille.

The paper of the evening on " Pavements of Cleveland Compared with Those of Other Cities " by James Ritchie, C. E., was then read by the Secretary, pro tem. A discussion on the paper by Messrs. Rawson, Culley, Claflen, Swasey and Porter, and Colonel Smith followed.

Meeting adjourned at 10.30 P.M.

A. LINCOLN HYDE, *Sec. pro. tem.*

The Montana Society of Civil Engineers.

EIGHTH ANNUAL MEETING, JANUARY 12, 1895.—The meeting was called to order by President Haven, in the Board of Trade Rooms, Granite Block, Helena, Mont., at 11 A.M.

There were present, Messrs. Keerl, Goodale, Page, Ryon, McNeill, Wheeler, Gutelius, Haven, Cumming, Hovey, McDonald, Scheetz, Smith, Carroll and McRae.

Applications for membership were read from Charles Maurice Allen, Charles Henry Palmer, Daniel Perrin Mumbrie, Maurice S. Parker and Charles Wright Mead.

Votes on the amendments to the By-Laws were then canvassed. Mr. Gutelius and Mr. Wheeler were appointed tellers. There were twenty-nine ballots cast on the first proposition, all " Yes." On the second proposition, twenty-eight " Yes " and one " No." On the third proposition, twenty-seven " Yes " and two " No."

There being a majority of votes cast for all the proposed amendments, they were declared adopted by the Society.

It was voted that the By-Laws regarding the counting of ballots for membership be suspended, and that those ballots be counted. Mr. Wheeler and Mr. Gute-

lius were appointed tellers. They announced the result and the President declared that the Society had elected the following persons members of the Society: Paul S. A. Bickel, James Breen, Charles Alexander Dewar, Francis Webster Blackford, Albert Alton Morris and Clayton Miller Thorp. Thereupon Messrs. Bickel, Dewar, Morris, and Thorp being present, took their seats.

Mr. Page and Mr. McNeill, appointed tellers to count the ballots for officers, announced the result, and the President declared that the Society had unanimously elected the following persons as officers of the Society for the year 1895: President, James S. Keerl; 1st Vice-President, Augustus M. Ryon; 2d Vice-President, James M. Page; Secretary and Librarian, Forrest J. Smith; Treasurer, A. S. Hovey; Trustee for three years, Charles W. Goodale; Member of the Board of Managers of the Association of Engineering Societies, James S. Keerl.

The President read the report of the Secretary as follows:

Helena, Mont., January 12, 1895.

RECEIPTS.

For entrance fees	$ 50 00
" dues for the year 1893	91 00
" " " " 1894	173 00
" " " " 1895	63 95
" miscellaneous receipts	12 00
Total	$389 95

EXPENDITURES.

Paid to A. S. Hovey, Treasurer, as per receipts herewith submitted, No. 1 to 17 inclusive	$389 95
Totals	$389 95

There is due from members for the year 1893	$ 30 00
For the year 1894	103 00
Amount overpaid by members and credited on the account for 1895	22 95

G. O. Foss, *Secretary.*

Helena, Mont, January 12, 1895.

Statement from the books of the Secretary, showing the expenditure of the Society during the year ending to-day. For details see warrants No. 99 to No. 131 in the hands of the Treasurer (No. 113 cancelled and 130 not presented for payment).

For typewriting and report of meetings	$ 27 35
" postage, expenses of officers	29 50
" sundry expenses, annual meeting, 1894	5 25
" publishing list of members	17 50
" binding newspapers, etc.	9 50
" extra bill of Associated Society	5 90
" printing notices, reports, letter-heads	98 20
" drawings for Journal, accompanying paper	8 00
" stationery for offices	11 55
" the JOURNAL OF ASSOCIATED SOCIETIES	134 50
Total	$347 25

G. O. Foss, *Secretary.*
per W. A. HAVEN.

It was moved and seconded that the report and statement of the Secretary be accepted and referred to the Trustees. It was so voted.

It was voted to pay the expenses of the Annual Meeting of 1895 from the funds of the Society.

The report of the Treasurer was then read as follows:

January 13, 1894, by balance cash on hand	$ 26 36
By amounts received at sundry times from G. O. Foss, Secretary, as per receipts on file in his office	389 95
Total	$416 81

EXPENDITURES.

Amount paid as per warrants herewith submitted, Nos. 99 to 131 inclusive, excepting No. 113 cancelled, and No. 130 not yet presented for payment	$347 25
Paid to H. J. Horn, Jr., per order of the President	2 00
Total expenditures	$349 25
January 12, 1895, balance on hand	67 56
A. S. Hovey, Treasurer	$416 81

No further business offering, the Society thereupon took a recess until 2 P.M.

2 P.M.

The first order of business was the installation of the new officers as announced in the forenoon.

The retiring President read his address as follows:

GENTLEMEN:—In retiring from the office of President, I congratulate you all upon the recent healthy growth of our Montana Society, not only in the number of its members, but in their professional standing. In looking over our list of members and referring to a catalogue of the members of the American Society of Civil Engineers, I find that 25 per cent. of our members are also members of that Society and that about one half of the remainder are qualified, both by age, experience and professional attainments for membership in that Society.

When our list of members was printed, February 12, 1894, the Society was composed of two honorary members (one of whom was also a member), seven associate members and forty-one members. During the year no change has been made in the list of honorary or associate members. One member living in Minnesota has withdrawn. Thirteen new members have been elected, making the total number of members at the present time fifty-three, and to-day the applications of five more persons for membership have been read.

The reports of the Secretary and Treasurer, which have been read to you, show that the Society is in a healthy financial condition. The renewed interest in the Society manifested by our members, and the desire for membership expressed by engineers, surveyors and others in all parts of the State, are due, I think, to the fact that our Society has taken an active part in movements for developing the resources of our State in a practical, scientific and economical manner, and has thus acquainted the people of the existence of our Society and of our ability and readiness to grapple with the problems that must be solved by our people. I will quote from a

letter which I have just received from one of your former presidents, congratulating us upon our present prosperity. He says: "The only way for civil engineers to advance is to make themselves felt, and there is no better way than by their united strength *in organization* and in taking up the questions in which their existence is concerned."

We now have before the Society two matters of vital importance, not only to ourselves, but to the whole State of Montana, viz., (1) "the measurement and appropriation of water," and (2) changes in the Statutes of Montana in the interest of a better system of location, construction and repairs for highways and highway bridges, with a view of reducing taxes and at the same time of obtaining better results in the expenditure of the road tax which now amounts to over $200,000 per annum in our State. Both of these matters will come before you to-day for your free discussion and final action.

The report of the Secretary shows an unusually large expenditure for printing, postage, and other expenses. This was incurred because the Society voted at its regular meetings, in November and December, to print a large number of the reports of the Committee on Water, and also that on County Surveyor and Road Laws, and to send copies not only to each member of the Society, but to the newspapers, members of the Legislature, County Commissioners, and other public men throughout the State, in order to enlist their support of the measures which we propose. I think it was money well expended, and for the benefit of the Society.

In the younger years of the Society, and up to the present time, we have had to avail ourselves of the charity of some of the members who have allowed us to occupy their offices, not only for our monthly meetings, but for the storage of our books and papers and for the work-room of our Society. My experience during the last three months as Acting Secretary as well as President, has convinced me that the Society should now have a room of its own, where it may have not only the desk, but book-cases for the rapidly-growing library, to which members can have ready access, and where they can read the current engineering literature and our many valuable books of reference. I recommend that, at the meeting to-day, a committee be appointed to secure permanent quarters for the Society, where its regular monthly meetings may be held.

The present Constitution and By-Laws seem to me to be defective. For instance, during the past year your Secretary has been absent from the State three-quarters of the time, and yet there appears to be no power, either in the Society itself or in any of the officers, to appoint a secretary *pro tem.*

During the absence of Mr. Foss, the duties of the Secretary were performed in a creditable manner by Mr. Cumming while he was in the city; but in Mr. Cumming's absence during October and November, I assumed the office of Secretary by virtue of the article of the Constitution, defining the duties of the President, viz., "He shall exercise all the powers and prerogatives appertaining to his office." In similar societies, the President is the executive officer, and it is his duty to see that the business of the society does not suffer by reason of the absence of any officer.

You have a board of three trustees—this seems a misnomer, as there is nothing whatever they hold in trust. I recommend that the Constitution and By-Laws be changed, so that in place of the trustees three directors may be elected, and that they, together with the President and Secretary, shall constitute a board of direction, who shall have full control of the affairs of the Society, with power to fill all vacancies in the elective offices, which may occur from any cause, until the Society can elect officers in the regular way.

During the last sixty days I have had considerable correspondence with the Chairman and Secretary of the Board of Management of the Association of Engineering Societies, regarding the policy of the Association in several matters. The member of the Board of Management, representing our Society, handed me the reports of the Secretary and letters from him and the chairman, and a list of ten questions to be voted upon, asking my advice thereon. As most of these questions referred to the financial situation, and thereby affected the treasury of your Society, and the pockets of each one of our members, I referred the matter to our Trustees, who directed me to instruct our member how to vote upon the several propositions. As there was a considerable difference between the views of our member of the Board of Management and the Trustees, I think it would be well if our Society should appoint a committee to investigate this matter and report the facts to the Society. All the papers relating to this subject are open to inspection, and it seems to me very important that our representative, when in doubt how to vote on any matter before the Association, should have a board of directors with whom he may consult at any time.

Our meeting in Butte, in October, was productive of good results to the Society, though uncontrollable circumstances prevented as large an attendance as we hoped to have. I hope that this feature of our Society may be continued.

I congratulate the non-resident members present at this meeting upon the fact that they reside along the line of the Northern Pacific Railroad, whose enlightened management recognizes that a meeting of such a representative body of men as the Montana Society of Civil Engineers contributes much to the material development of the State, and thereby to an increase of business for its lines, and I am sorry that it has no direct line between Butte and Helena.

Thanking you all for your ready aid in my efforts to promote the welfare of the Society during the two and a half years of my presidency, I take pleasure in introducing to you your new President, Mr. James S. Keerl, of Helena.

Mr. Keerl then made a short address, as follows:

Gentlemen:—I wish to relieve at once any apprehension under which you may be laboring, due to the suggestion of our retiring President that I should follow him with an inaugural address, for it is far from my intention to afflict you in this manner at this time. If I comply with our By-Laws, I shall try your patience sufficiently, a year hence, by the annual address therein prescribed.

It is scarcely necessary for me to assure you of my high appreciation of the honor you have conferred upon me by electing me your President for the ensuing year.

Under the very able management of our retiring President, our Society has advanced to a commanding and respected position in the estimation of the public, and I trust that I may, with your assistance, maintain its dignity and utility, and be in a measure at least, instrumental in forwarding its interests and those of the profession it represents. In a new State like Montana, a society of engineers has a wide and most interesting field for the exercise of the professional attainments of its members. Where we find existing faulty legislation affecting technical matters, the responsibility is upon us to use our best efforts to secure desirable corrections. The need of new legislation upon subjects of an engineering character should excite our deep interest, and we should use our best endeavors for the enactment of such laws which, while assuring the best interest of the State, will reflect credit upon us as engineers both patriotically and professionally.

Much earnest work has been done by some of you on these lines during the

past year, and, as a result, two committees will report to you, recommending Acts for presentation to our Legislature now in session. I bespeak for them your careful consideration and your best efforts to secure their passage after they have been duly received and approved by you.

Mr. Keerl then took the chair.

The report on water was then taken up and the Secretary read an Act establishing a standard for measurement for water, defining the equivalent of a miner's inch and repealing Section 1262, Division 5, of the Compiled Statutes of the State of Montana :

Be it enacted by the Legislative Assembly of the State of Montana :

Sec 1. Hereafter a cubic foot of water per second of time shall be the legal standard for the measurement of water in this State.

Sec. 2. Where water rights expressed in miner's inches have been granted, one hundred miner's inches shall be considered equivalent to a flow of two and one half cubic feet per second ; two hundred miner's inches shall be considered equivalent to a flow of five cubic feet per second, and this proportion shall be observed in determining the equivalent flow represented by any number of miner's inches.

Sec. 3. Section 1262, Division 5, of the Compiled Statutes of the State of Montana, and any laws in conflict with this Act, are hereby repealed.

The President : This report of Professor Ryon's is a very thorough one and certainly reflects great credit on the Society ; and while it is quite lengthy and full of formulas, it might be well, for the benefit of the members present, to have the "conclusions" read.

The Secretary then read the "conclusions."

Mr. Haven moved an amendment, to define, in the Act, for the information of placer miners, ranchmen and the "Old Timers," the quantity of water, in gallons, that is contained in a cubic foot. Professor Ryon seconded the amendment. The Act was then discussed at great length by Messrs. Page, Ryon, Keerl, Haven, Carroll, Goodale and Scheetz. The amendment was then adopted, viz.: to insert in line 2, after the word "foot," the following, "or 7.48052 gallons ;" after "feet," in line 7, "or 18.7013 gallons ;" after "feet," in line 10, "or 37.4026 gallons." The report and Act were then unanimously adopted as embodying the views of the Society, and it was voted that a committee of five be appointed to see that they be introduced in the Legislature, and to urge its passage. Messrs. Ryon, Cumming, Carroll, Scheetz and Tappan were appointed members of this committee.

The chairman of the committee on the memorial of our former president, Col. W. W. DeLacy, reported that it had nearly completed its labors and would submit the memorial to the Society at the monthly meeting in February.

The report of the Committee on County Surveyors and Road Laws was called for.

Mr. Haven : The committee sent to me, December 20th, one copy of its report with a proposed Bill. I immediately had 150 copies printed, and mailed a copy to every member of the Society and to county commissioners and others interested in good roads all over the State, requesting them to send me in writing their suggestions for alterations or amendments. By the the middle of this week about a dozen of these had come in, and I called a meeting of the committee, who met here yesterday morning and so amended the Bill as to meet the suggestions received. At 10 o'clock this forenoon they handed me seven pages of closely-written manuscript. At 2 P.M. I received 100 printed copies of the report which Mr. McNeill, the chairman, will now present to you. You will find this different in many respects from the one sent you December 22d.

Mr. McNeill then explained what was sought to be accomplished, viz., to place the entire charge of the laying-out, construction and repairs of all county roads and bridges in the County Surveyor, who should be held responsible by the County Commissioners for the condition of the roads at all times and be made by law a member of all boards of "road viewers;" the County Surveyor to make and see to the execution of all contracts about roads and bridges, and to take the place of the present "road supervisors;" all road taxes to be paid in cash instead of being worked out, and thus, by expending the annual road tax in a systematic manner, to eventually reduce taxation and apply the tax in an economical manner and make a beginning of good roads in all the valleys and mountain passes of Montana.

In order to bring the whole matter before the meeting, both reports, that of December 22d and that of to-day, were then read by the Secretary. A long discussion was then had, all the members present taking part in it, as well as members of the Legislature, and County Commissioners, Mr. F. H. Ray, who represented the "Wheelmen," and surveyors not members of the Society. Questions of the constitutionality of the Act were discussed in an able manner by the engineers and "old-timers."

At six o'clock the meeting took a recess for dinner until half past seven. In the evening session the discussion was resumed. About thirty visitors were present, mostly men interested in our Road Law, among them two of the Commissioners of Lewis and Clarke County, several lawyers, judges and members of the Legislature. Questions of grades and highways, ditches, bridges, contracts for construction and repairs, and specifications were discussed. All the visitors heartily endorsed the general object of the Society, and hoped it would be able to overcome all the objections raised to the present proposed bill. They assured the Society of their hearty co-operation.

It was finally voted that the reports be referred back to the Committee, Mr. Cumming being substituted for Mr. Baker, who was not present. The Committee was instructed to employ legal advice and to report to an adjourned meeting of the Society on Monday evening.

The thanks of the Society were voted to Messrs. Wheaton and Muth, County Commissioners and to Judge O'Bannon for their advice and suggestions during the evening.

The Secretary was instructed to send a letter to the General Manager of the Northern Pacific Railway Company, through A. D. Edgar, General Agent, thanking him for his courtesy in granting to all of our members residing along its lines transportation to and from Helena.

It was voted that ballots upon the applications for membership, read at the morning session, should be sent out, to be canvassed at the next regular meeting.

Mr. Goodale.—For several months Mr. Haven has not only filled the office of President, but has acted as Secretary in the absence of that official, and I think the thanks of the Society should be given to him. It was so ordered.

Mr. Haven.—I have letters from Mr. Trautwine, Secretary of the Association of Engineering Societies, and from engineers of other societies ranging all the way from Boston to Tacoma and San Francisco, congratulating the Society upon its growth. I do not think it is due to me but to the action of the Society themselves in taking hold of practical matters of interest to the State.

Mr. McRae.—I move that a vote of thanks be given to Professor Ryon for the able manner in which he has treated the question of the Measurement of Water. He has been at a great deal of labor and possibly expense to himself, and I think he has done his work exceptionally well.

A vote of thanks was given to Professor Ryon.

The Society then, at 10.30 P.M., adjourned until Monday evening, when the members held a social function lasting until about midnight.

JANUARY 14TH.

The meeting was called to order by the President at 8 o'clock.

Tho Committee on County Surveyor and Road Laws reported that it had been at work since the adjournment on Saturday evening; that it had taken legal advice and had consulted with Mr. F. H. Ray and with one of the Commissioners of Lewis and Clark County.

On motion of Mr. Haven it was unanimously ordered that the thanks of the Society be extended to Messrs. McNeill and Gutelius, who had been almost constantly at work since Friday morning, in order that they might prepare their report in time for this meeting, and who would have to remain in Helena one or two days after the close of the meeting, and that their expenses be paid from the funds of the Society.

A vote of thanks was given to Mr. Goodale for his efforts in Butte in increasing the membership of the Society.

The suggestions contained in the address of the retiring President were referred to a committee of one. The President subsequently appointed Mr. Goodale as this committee.

The Secretary was instructed to convey to the officers of the Board of Trade the thanks of the Society for the use of their rooms during the annual meeting; also to Mr. Gardiner for his active co-operation and for his valuable legal advice in preparing the Acts and Bills for the Legislature.

The County Surveyor Bill was then read. A few minor changes were made and the Bill, as amended, was adopted for submission to the Legislature with the Society's approval.

The Road Law, as reported by the committee, was then read. It was discussed, section by section, and some amendments were made. Finally, it was unanimously adopted as embodying the sense of the Society as to what the Montana Road Law should be.

It was then voted that the committee be instructed to supervise the preparation of three typewritten copies of the proposed Act, in proper shape for presentation to the Legislature; one copy thereof to be placed, with the County Surveyor Bill, in the library of the Society.

It was voted that a committee of five be appointed to present both bills to the Legislature and to watch over them until their final passage. (The President appointed Messrs. McNeill, Cumming, Harper, Gutelius and Dewar.)

A full stenographic report of the meetings, covering forty-six typewritten pages, is on file with the Secretary.

At 11 o'clock the meeting adjourned.

F. J. SMITH, *Secretary*.

Boston Society of Civil Engineers.

JANUARY 23, 1895.—A Regular Meeting of the Boston Society of Civil Engineers was held at its rooms, 36 Bromfield Street, Boston, at 7.45 o'clock P.M. President William E. McClintock in the chair. 121 members and visitors present.

The record of the last meeting was read and approved.

Messrs. Albert S. Cheever and James W. Rollins, Jr., were elected members of the Society.

On motion of Mr. FitzGerald it was voted to choose by nomination from the floor a committee of three, to report at this meeting the names of five members to serve as a committee to nominate officers. Messrs. Fred. Brooks, Henry Manley and John R. Freeman were chosen as the committee. Later in the meeting this committee reported the names of Desmond FitzGerald, A. E. Burton, R. A. Hale, F. W. Hodgdon and F. C. Coffin, and on motion these gentlemen were elected the committee to nominate officers for the ensuing year.

Mr. Henry Manley was appointed a committee with full powers to make the necessary arrangement for the annual dinner of the Society, and the sum of $50.00 was appropriated for the incidental expenses of the dinner.

The President announced the deaths of Phineas Ball and Lincoln C. Heywood, members of the Society, and on motion he was authorized to appoint a committee to prepare memoirs. The committees appointed consisted of Messrs. Charles A. Allen and Lucian A. Taylor on memoir of Mr. Ball, and George A. Carpenter and Morris Knowles on memoir of Mr. Heywood.

While waiting for the committee to report a nominating committee, Mr. FitzGerald gave an interesting account of the recent annual meeting of the American Society of Civil Engineers in New York.

The thanks of the Society were voted to James A. Fenno, Supt. of the Boston, Revere Beach & Lynn R. R. for courtesies shown the members of this Society on the occasion of the trip to the tunnel at East Boston.

The literary exercises of the evening consisted of a very interesting paper by Mr. Corydon T. Purdy, C.E., of New York, entitled "The Use of Steel in Large Buildings" The paper was very fully illustrated by lantern views of a number of the most noteworthy high buildings in New York, Chicago and Buffalo.

After passing a vote of thanks to Mr. Purdy for his valuable and interesting paper. the Society adjourned.

S. E. Tinkham, *Secretary.*

Association of Engineers of Virginia.

Roanoke, Va., January 26, 1895.—The annual meeting of the Association was held January 26, 1895, the President, Mr. Charles S. Churchill, in the chair. The directors reported as follows:

Total members on roll, January, 1894	86
Resigned or dropped from roll during the year	50
Members in good standing on roll, January 26, 1895	36

Active members, 34; honorary members, 2.

Treasurer's report below shows the receipts and disbursements for the year 1894:

Receipts.

Cash balance, January, 1894	$ 1 92
From initiation	13 75
" annual dues of 1892	12 50
" " " 1893	30 00

From annual dues of 1894	$176 25
" " " 1895	140 00
" sale of furniture	113 50
" publication	1 00
	$488 92

DISBURSEMENTS.

For advertising	$ 2 10
" rent	177 32
" incidentals	46 10
" good roads convention	10 00
" publications	94 88
Cash balance	158 52
	$488 92

The year 1894 has been a memorable one in the history of our Association, having been witness to the scattering of our members to all parts of the country to meet the requirements of their profession.

The above statements of membership and finances show that the expectations entertained at the beginning of the year were not fully realized. At the last annual meeting there was to the credit of the Association in uncollected dues from members supposed to be in good standing, $552.50. It was expected that an improvement in business would make possible the collection of a large portion of this amount and so enable the directors to make a publication of the papers on hand. After much labor on the part of our Treasurer, our collection on back dues amounted to only $218.75, or a total of less than our expenses plus our indebtedness on the last issue of our proceedings. At the fall meeting, on recommendation of the Directors, it was decided that the Association of Engineers of Virginia should give up its old room in the Terry Building, Roanoke; sell its useless furniture (retaining desk, press, etc.); pay off its indebtedness with the amount realized by the sale; accept the kind offer of the Norfolk and Western Railroad Company, allowing us the use of a room in its office building, at Roanoke, for records and meetings; and, finally, join the "Association of Engineering Societies," so as to secure to our members monthly publications during the year 1895.

All these plans have been completed. Thirty members have paid their dues in advance for the year 1895, and we count our active membership as thirty-four. The Association is out of debt. There is $158.52 in the treasury to meet all expenses during the year 1895, and our Treasurer estimates that our expenses for that year will be only $145. Finally, our society has formally become a member of the "Association of Engineering Societies," along with the societies of Boston, Cleveland, Chicago, St. Paul, Minneapolis, St. Louis, Kansas City, Denver and Montana; and a monthly publication of considerable value will reach our members, beginning with the January number of 1895. These proceedings will be sent direct to our members by the "Association of Engineering Societies," the first number being due about March, 1895.

During the year 1894, three regular meetings and six monthly informal meetings were held, during which twelve topics were discussed and six papers were read and referred to the Committee on Publication. The summer meeting at Alleghany Springs was regarded by all a success.

The building laws compiled by the Association were adopted by the City of

Roanoke. Our Association took an active part in the presenting of a form of road law before the State Legislature, and considerable expenditure was made by the Association and by its individual members to secure action at an early date.

This report of the Board of Directors was approved.

The President announced the election of officers for the year 1895 to be in order, and appointed as scrutineers of the ballots, Messrs. Crueger and Dunlap, who reported as follows: For President, J. C. Rawn; Vice-president, M. E. Yeatman (to serve two years); Secretary, John A. Pilcher; Treasurer, James R. Schick; Directors (to serve three years), Charles S. Churchill, L. S. Randolph, and H. C. Macklin. Mr. Charles S. Churchill was elected as the representative of the Association of Engineers of Virginia on the Board of Management of the "Association of Engineering Societies."

The Articles of Association of the "Association of Engineering Societies" were adopted, and the Secretary authorized to notify that Association accordingly. The Secretary was authorized to have printed a list showing addresses of all members, for the use of the "Association of Engineering Societies."

A paper by Mr. J. E. M. Hanckel, entitled "Road Improvements in Knox County, Tennessee, and Fulton County, Georgia," was read, and, after discussion, referred to the Publication Committee. This paper re-enforced the arguments brought out before in this Association for the adoption by the State of Virginia of the Road Law as proposed by the Association of Engineers of Virginia, and showed that convict labor can be most successfully employed on this class of public improvements.

J. A. PILCHER, *Secretary.*

Association of Engineering Societies.

Vol. XIV. FEBRUARY, 1895. No. 2.

PROCEEDINGS.

Western Society of Engineers.

The Annual Meeting (323d of the Society) was held in Parlor 44, Grand Pacific Hotel, Chicago, at 8 P.M., on Wednesday, January 2, 1895.* 111 members and guests present.

President H. B. Herr took the chair and called the meeting to order. No objections being made, the minutes of the previous meeting were approved as printed.

The report of the Board of Directors was read by the Secretary, as follows:

At the meeting of the Board held December 12th, the applications for membership of Messrs. George B. Christie, Ferd G. Gasche, George A. Lederle and Jesse Lowe were received and placed on file.

The Committee on Nominations submitted the following list of nominations for the offices to be filled at the annual election :

President,	Willard A. Smith.
First Vice-President,	Onward Bates.
Second Vice-President,	T. T. Johnston.
Secretary,	Thomas Appleton.
Treasurer,	David L. Barnes.
Librarian,	Charles J. Roney.
Trustee,	Hiero B. Herr.

The list was signed by the entire Committee and by eight other members of the Society.

Messrs. Bates, Appleton and Herr declined the nominations.

At the meeting of the Board held December 19th, a petition signed by ten members of the Society was received, nominating Mr. Horace E. Horton for Presi-

* Manuscript received February 25, 1895.—*Secretary, Assn. Eng. Socs.*

dent, and Mr. Charles L. Strobel for First Vice-President. Another petition was received signed by ten members nominating Mr. Charles J. Roney for Secretary.

Mr. Strobel declined the nomination for First Vice-President.

In accordance with the provisions of Section 3 of Article IX of the By-laws, the Board made the following nominations, so as to present a ticket with two names for each of the offices:

For First Vice-President, Daniel W. Mead, L. P. Morehouse.

For Second Vice-President, Henry C. Draper.

For Secretary and Librarian, Edwin G. Nourse.

For Treasurer, W. L. Stebbings.

For Trustee, John W. Cloud, G. A. M. Liljencrantz.

The time for closing the polls was fixed at 12 noon, January 2, 1895. Messrs. J. J. Reynolds, Ralph Modjeski and R. H. Bethel were appointed tellers to receive and count the votes at the annual election.

The resignations of Messrs. Geo. D. Stonestreet, Wm. Forsyth and Charles W. Stewart were accepted.

Bills amounting to $140.13 were approved and ordered paid.

At the meeting of the Board held this day, the following named gentlemen were elected to membership:

As members, W. I. Babcock, George B. Christie, Howard A. Coombs, Ferd G. Gasche, Chas. W. Hotchkiss, George A. Lederle, Jesse Lowe, John C. Nickson, H. F. J. Porter, Edwin C. Reynolds, William H. Stearns and Charles H. Wilson.

As Associates, Charles E. Schaufller and C. H. Vehmeyer.

The resignations of F. L. Clerc, W. C. D. Gillespie, George D. Hersey and Charles W. Maynard were accepted.

Bills amounting to $316.32 were approved and ordered paid.

The following report of the Committee on Life Members was accepted and referred to the Society:

To the Board of Directors of the Western Society of Engineers:

The Committee to whom the standing of the Life Members of the Society was referred, submit the following report:

The Western Society of Engineers came into existence at the time of its incorporation in 1880. It was a new organization at that time, its only connection with the old Engineers' Club of the Northwest being that the members of that club became the charter members of the Society.

The provision of Section 6 of Article IV of the Constitution provides that a member who has been a member for 20 years may become a Life Member in the manner provided in the By-Laws.

Section 7 of Article IV of the By-Laws provides that any member who shall have paid all fees, dues or assessments that may have accrued against him for a period of 20 consecutive years, shall, *upon vote of the Board of Directors at any regular meeting*, become a life member.

Your Committee does not see how the provision of the Constitution can be held to cover a period antedating the organization of the Society. Your Committee is unable to learn that any such votes have ever been passed by the Board of Directors. In a strictly legal view, the Society has no Life Members, except Mr. Morehouse, who was specially made so by vote of the Society.

Your Committee, however, believes that it would be unwise to enforce this legal condition in relation to those who have been treated as Life Members in the

past, and recommends that they be excused from payment of all past and present dues; but that in future no other member shall be considered a Life Member until made so by vote of the Board of Directors, which vote cannot be passed until 20 years after the incorporation of the Society, except in case where a member makes a single payment of $100, as provided by the Constitution.

GEO. S. MORISON, } *Committee.*
R. W. HUNT,

The Committee on Quarters reported that it had received an advantageous proposition from the agents of the Monadnock Block, and considered it advisable to accept the proposition and remove the Society's property to that location.

The report of the Committee was accepted, and the Board recommends that the Society appoint the same Committee with power to act.

PRESIDENT HERR:—There being no objection, the report of the Board of Directors will be received and placed on file.

Reports of Committees being in order, the Secretary read the report of the Committee on Memoir of the late Orlando H. Cheney.

IN MEMORIAM.

ORLANDO H. CHENEY,
Died April 13, 1894.

The subject of this memoir was born in Ashtabula, Ohio, November 1, 1839. He received his primary education in the public schools of that city, and afterwards studied civil engineering in the Grand River Institute. Subsequently he was engaged for two years as a member of a corps of engineers on railroad construction in the State of Ohio.

At the breaking out of the War of the Rebellion, Mr. Cheney enlisted as a volunteer in the 11th New York Battery, and served with distinction through the whole period of active hostilities. His battery formed part of the army of the Potomac, and took part in all the battles in which that army was engaged, Mr. Cheney participating in all of these engagements, except during the time he was confined in the hospital, having been severely wounded in the battle of Gettysburg, July 3, 1863.

After the close of the war, Mr. Cheney located in Chicago, and resided there continuously up to the time of his death. For eight years he was connected with the firm of Wolcott & Fox, City and County Surveyors, Mr. Wolcott at that time occupying the official position of County Surveyor.

He was appointed assistant engineer in the Street Department of the city in 1874, and in that capacity had charge of the construction of several viaducts, including the Blue Island and Milwaukee Avenues, in addition to a very extensive list of street improvements in the West Division.

From this position he was promoted, in 1881, to the responsible office of Superintendent of Sewers, which he held continuously up to the date of his death.

In this difficult position Mr. Cheney made a record for ability, integrity, tact and close attention to all details of business, which it is safe to say has been equalled by few men holding political offices in this country.

The fact that he remained undisturbed through so many changes of administration is a proof of the esteem in which he was held by his superiors in the city government, while he won the respect and affection of his subordinates and employees, almost without a single exception.

The taxpayers and property owners felt that their interests were safe in his hands, and even the contractors, whom he held to a strict discharge of their obligations, were free to admit that he was a thoroughly fair-minded man, and that no just claims of theirs ever failed to receive due consideration from him.

But perhaps Mr. Cheney's most prominent characteristic as a public official was his practical realization of the fact that such an official is, first and foremost, the servant of the public. No one who came to him for information or advice could complain of a lack of courteous attention ; however busy he might be, he would take personal charge of the applicant for information and look up the data required, often at a considerable sacrifice of time ; while a poor man was treated as courteously as a millionaire.

The immense extension of the corporate limits of Chicago, which took place during Mr. Cheney's incumbency of the position of Superintendent of Sewers, caused an enormous increase in the work of that department, and required executive ability of a high order, together with unremitting attention to details, on the part of the department chief, in order to get and keep the records and accounts in proper shape. Previous to the annexation of the suburban districts, all main sewers were paid for out of the general tax levy, but thereafter the special assessment plan was adopted, involving a great deal of extra office work and important changes in the system of bookkeeping.

During the last four years of Mr. Cheney's life many more miles of sewers were constructed in the city of Chicago than the total existing mileage inside the corporate limits at the time of his appointment as head of the Sewer Department.

In 1871 Mr. Cheney married Miss Laura McMahon, who lives to mourn his loss. Four children (one son and three daughters, all of whom are living) were the result of this union.

Mr. Cheney was elected a member of the Western Society of Civil Engineers April 6, 1886.

He was a member of long standing in the Masonic fraternity, and had attained high honors in that organization, being Past Master of Cleveland Lodge No. 211, A. F. & A. M., Past High Priest of Washington Chapter No. 43, and Past Eminent Commander of Chicago Commandery No. 19, Knights Templar. He was also a member of U. S. Grant Post No. 28, G. A. R.

Mr. Cheney was particularly happy in his home life. His genial character, so admired by his friends, doubly endeared him to his family.

To them, in their bereavement, the sincere sympathy of this Society is tendered.

Sam'l G. Artingstall,
Robert P. Brown,
F. H. Davies.

On motion, it was voted that the report be accepted and placed on file, and that a copy be sent to the family of the deceased.

President Herr :—Under the head of new business I would refer to a portion of the report of the Board of Directors which relates to quarters for the Society. Our present lease expires on the 30th of April next. The Board appointed a Committee on Quarters, and this committee has done some very good work. It has a proposition from the agents of the Monadnock Block for about 1,050 square feet of space for nearly the same rental as we are now paying in the Lakeside Building for about 720 square feet.

It was moved by Mr. Randolph that the same Committee (Messrs. Strobel,

Appleton and Roney) be appointed a Committee of the Society with power to act in securing quarters for the Society. Motion seconded and carried.

President Herr:—The tellers now have ready their report of the election, which I will read:

Chicago, January 2, 1895.

To the Western Society of Engineers:

We, the undersigned Election Judges, appointed by the Board of Directors, having canvassed the votes cast for the election of officers for 1895, respectfully submit the following result.

Total number of votes cast, 170, of which

For President.

Mr. Horace E. Horton	122
Mr. Willard A. Smith	47

First Vice-President.

Mr. L. P. Morehouse	92
Mr. Daniel W. Mead	76

Second Vice-President.

Mr. T. T. Johnston	92
Mr. Henry C. Draper	77

Secretary and Librarian.

Mr. Charles J. Roney	138
Mr. Edwin G. Nourse	31

Treasurer.

Mr. David L. Barnes	105
Mr. W. L. Stebbings	63

Trustee.

Mr. G. A. M. Liljencrantz	98
Mr. John W. Cloud	72

James J. Reynolds,
Ralph Modjeski,
R. H. Bethel.

I therefore announce the following officers elected for the present year:

President, Horace E. Horton.
First Vice-President, L. P. Morehouse.
Second Vice-President, T. T. Johnston.
Secretary and Librarian, Charles J. Roney.
Treasurer, David L. Barnes.
Trustee, G. A. M. Liljencrantz.

The Secretary:—Mr. President, there is one thing that I hope will not be overlooked. During the whole of this year we have held our meetings in the Grand Pacific Hotel, without any expense to the Society. Last year we paid from $10 to $15 per night for the use of a meeting-room. The management of this hotel certainly deserves the thanks of the Society for their generous provision for our welfare in this respect.

Mr. R. P. Brown moved that the thanks of the Western Society of Engineers be extended to Messrs. Drake, Parker & Co., of the Grand Pacific Hotel, for the free use of a meeting-room for the Society during the past year, stating that the Society fully appreciates their kindness. Motion seconded and carried.

President Herr:—Before adjourning to the banquet which now awaits us, I wish to thank the members for their assistance during the past year, and for not making the President any more trouble than seemed necessary. I hope that the next year may be more prosperous than this has been, and that you may sustain your new President as fully as you have the retiring one.

The meeting then adjourned to the banquet hall adjacent, where, after a time had been spent in appeasing the hunger and thirst of the members and guests, the meeting was again called to order by President-elect Horton, Chairman of the Committee on Excursions and Entertainments, and a song, "The Chorister," by Masters Davison and Soden of Grace Church Choir, accompanied by Professor Henry B. Roney, was listened to.

The report of the President for the year 1894 was then read by the retiring President, Mr. H. B. Herr, as follows:

The Western Society of Engineers:

Gentlemen:—Our By-Laws provide that "at the Annual Meeting the President shall present a report containing a statement of the general condition of the Society and a summary of engineering progress during the preceding year." This latter provision was probably framed when we were styled the "Civil Engineers' Club of the Northwest," and the term "engineering," was meant to be used in a limited sense, to include only what might be classed as civil engineering. A summary of such progress might be essayed, but to summarize the progress of all branches of engineering, and present it at one reading, seemed impracticable. So I trust you will pardon my limiting the report to the "condition of the Society."

Those members who availed themselves of the opportunity for attending our meetings, visiting our library room, and enjoying the delightful excursions made, have much of the information this report contains, but those who could not, or did not, come into such close contact with the operations of the Society, may find something of interest in what will be briefly stated.

As per our Secretary's report, we commenced the year just closed, with 338 members of all grades, of whom 5 have since entered into their last sleep. Resignations have added 14 more to our losses. Yet at the close of the year our membership numbers 416, including all grades. There are several cogent reasons for this handsome rally to our ranks. The able and affable manner in which our Secretary conducted his office; the growth in usefulness of our library; the pleasant and profitable excursions made; the laudable efforts of several members; the appointment of a Reorganization Committee; and the general policy of our Board of Directors. These were undoubtedly the main inducements offered which attracted our new membership.

By pursuing the same economical financial policy as that inaugurated by the preceding Board, our Directors paid out of last year's income, for expenditures incurred during 1893, $781.72; also all the expenses for 1894, and have saved out of that income a small amount ($96.42) which they present, as a New Year's gift, to the incoming Board. In addition, they hand over all collections, to date, of dues for 1895. (See Secretary's report). It is worthy of remark that this is the first time for some years that the income for any one year was not raided for payment of expenses of the preceding year. May we not then rejoice in the realization of a healthy financial basis? Yet it is far from a solid one. This will only be when all our ordinary expenses, at least, are paid out of the income for the year

in which they are incurred, without a subscription list, and after placing all initiation fees in a permanent fund.

In taking up their labors, the Board of Directors, in comparing the probable expenses, including those for 1893 unpaid, with the probable income for the year, found that the necessary expenditures for assessments to be levied by the Association of Engineering Societies, rent, janitor services, printing proceedings, stationery, postage, etc., would probably absorb more than the income. On account of the unexpectedly large addition to our membership, this hypothesis was incorrect, as shown by the small balance the other way.

Under such conditions, they found it inexpedient to recommend the payment of salary to the Secretary and Librarian from the Society funds, but favored a subscription for that purpose. The amount of this subscription, as determined by the Society, was to be $1000.00. Surely a paltry sum for the valuable services rendered, yet it was not all collected, though a special committee for the purpose made an earnest effort towards its consummation. The deficiency of $102.60 was paid by the Board from the Society funds, with the idea that any further collections should go to that fund.

The necessity for resorting to subscription for the payment of indispensable services was one of several important considerations which led to the recommendation, by the Board, of our withdrawal from the Association of Engineering Societies.

A library room, with a competent librarian in attendance daily during ordinary business hours, was a new feature inaugurated last year. Such attendance could not have been had but for the generous offer of Mr. Roney to give the attendance for such renumeration as the Society might award him, and for benefits to result towards building up a creditable library.

At the beginning of the year we had about 1,070 bound volumes, about 4,200 unbound volumes, magazines and pamphlets, with about 900 maps, charts, atlases, etc. These were uncatalogued, and of little use to the Society. Now we have about 2,000 bound volumes, and about 7,800 unbound volumes, periodicals and pamphlets with a large increase of maps and charts. About 2,000 of these are classified and listed for ready reference, and a librarian is in attendance. From my own observations I am sure many members can testify to profitable time spent in gleaning therefrom during the past year.

The great accessions to the library must be attributed to the earnest efforts of our librarian in soliciting, and the liberal spirit of a number of our members in making donations, aided by such assistance as the Committee on Library afforded. The meagre salary, $500.00, paid the librarian, Mr. Roney, for his valuable services during the year, was, as you all know, entirely incommensurable with the value received, and the thanks of the Society are due him for his unselfish zeal in devoting so much of his time to our benefit. From what has been done in the past year, may we not hope to secure in the near future, to the profession and to this city, a library creditable to the times, the place, and our Society?

When we consider the secretarial labors incident to the holding of 13 meetings of the Society; 27 meetings of the Board of Directors, with a great deal of committee work, looking up papers to be read before the Society (13 in number last year), and the many other calls upon the Secretary's time, we must admit that such services are worth much more than the paltry $500.00 he received for the entire year's work, if efficient service is given. That our Secretary, Mr. Appleton, has conducted the affairs of the Society in a highly satisfactory manner, is evident to

every member of our Board of Directors, at least. The records are in admirable condition, and we have prospered well under his careful methods and general comradeship; he is eminently entitled to the thanks of the Society.

Excursions to various places of interest and instruction were a marked feature of last year's conduct of the Society. Our Committee on Excursions and Entertainment deserves our thanks for the valuable time devoted to our pleasure and our general welfare in planning and carrying to completion so many pleasurable excursions, and without using a dollar of the Society funds.

At our February meeting, a Committee on Reorganization was created for the purpose of preparing a new Constitution and By-Laws, adapted to the needs of an Engineering institution on a higher and more national plane than our present organization. This Committee commenced its labors with much enthusiasm and gave promise of a great stride towards that eminence which we should reach at an early day. But alas! the summer heat came, and, like the prairie's verdure, it withered, but not to revive again with the cooling rains of autumn, as did the grass on plain and slope; so we are still under the old Constitution and By-Laws. And this in Chicago!—where are monuments on every hand proclaiming such rapid advances in business, in art, in architecture and engineering as are not, and have not been, elsewhere on this planet.

Engineers have been styled—and properly too—the pioneers of civilization. Why then does our Society follow in the wake of this stupendous march onward? Why not leap to the front, keeping pace with our City's progress, and take a leading place amongst the Engineering Societies of this country? Why not take up the Chicago spirit which secured the site for, then conceived and carried to completion, the grandest World's Fair mortals have ever beheld? That spirit, which is cutting through soil, drift and rock, our ample drainage channel, magnificent in its proportions, invaluable in the benefits it will secure to our City, and eventually to the commerce of the entire country? That spirit, determination and enterprise, in short, which has made Chicago the wonder of the world? In my opinion, Gentlemen, you will be "behind the times," in comparative obscurity, until you take on a National character, and stand upon the high plane compatible with nationality.

Had our business men been terrified by the New York idea, that Chicago was not competent to present a successful exhibition to the world, and yielded to the demands of that city, the site for the World's Exposition, is there one of you to-day who will say that a city of such magnificence would have been erected there as was the fair "White City" reared upon one of our primeval swamps? Why then heed the mutterings, from that same quarter, against our advancement to the highest place, and against the publication of our own productions, as is done by almost every other kindred organization the world over? See editorial in *Engineering News*, November 15, 1894. You should all read that. It is well calculated to increase the ranks of our "turbulent members." The last two words are quoted from the editorial.

Although we may congratulate ourselves for the progress made in certain directions during the year, I must confess that all was not accomplished which should have been, and might have been effected under a stronger guiding hand. Let me assure you, however, that any remissness on my part was due to my incapacity for the honorable position you thrust upon me, and not to willful negligence or lack of interest in the Society's welfare.

I wish to make note of my high appreciation of the consideration and courtesy accorded me by the officers and members generally. Thereby you and they

greatly facilitated my labors as presiding officer, and made for me a pleasurable duty, what had otherwise been a disagreeable task.

My greatest pleasure in the way of my official functions comes at this moment, in proposing the health of my wisely selected successor. He is known to you as one of our most useful members, one of our best engineers, and I know he will be one of our very best presidents.

Long life and prosperity to our genial fellow-member, and a happy reign to our President, Mr. Horton.

Mr. Horton:—The members of the Society know that the Board of Directors is required to see that at least two names are on the ticket for each office to be filled at the annual election. On one occasion the Board had to make the entire list. I have been honored with a place on the ticket so frequently, and have so often been "turned down" without an opportunity to make a speech, that I am now placed in an unexpected position, and have nothing to say in the way of an address, and in that connection I will call on Mr. Willard A. Smith, who will, I trust, say those things that I would like to say.

Mr. Willard A. Smith.—Mr. President and Gentlemen, this is hardly fair. Mr. Horton and I made a blind deal on this matter and had an excellent address prepared between us, and as he was the successful candidate he should have delivered it, and now, with that address in his inside pocket, he calls on me for a speech. . . . I can only take this occasion to congratulate the Society on the very decided progress which it has made during the year, and which it has so admirably crowned in its selection of officers for the coming year. I predict for the Society a year of greater prosperity than it has ever yet had. I fully agree with the remarks of our retiring President regarding the future of the Society and what it should be. I fully agree with him that no men and no society ever achieved greatness without first having planned for greatness and attempted it, and that this Society will never meet the full demands of its location, will never rise to the opportunity which is its opportunity, until it does plan for great things. Those who always fear that they may be going ahead too fast, never will get there. That is especially true of societies of this kind. It is especially true of Chicago. . . .

If we have the ambition, if we have the nerve to attempt it, we may achieve very great things. Chicago looks to us to do it, the country looks to us to do it, the world looks to us to do it. I believe fully that we should reorganize and make every attempt in our power to place ourselves in that position which our retiring President has so well placed before us to-night.

Mr. Horton then called on Mr. N. B. Patton, President of the Municipal Improvement League, who spoke of the work of the League in attempting to guide public sentiment and official bodies so as to avoid the construction of monstrosities.

At the suggestion of Mr. Horton, Mr. Appleton then read the following communication from Mr. E. L. Corthell:

"Mr. E. L. Corthell sends to Mr. Appleton the compliments of the season and best wishes for the new year for himself and the society he has so ably served the past year. May there grow out of this year's hard work and out of the abundance of good elements and talents, a greater society on a broader basis and a deeper foundation. Health is returning.

"Berne, Suisse, December, 1894."

Mr. Randolph :—May I suggest, Mr. President, that this Society transmit to our ex-President its new-year's greetings, and the hope that he may be speedily restored to health.

Mr. Horton :—The sentiments shall be sent as the sentiments of the Society. (A telegram was sent by cable to Mr. Corthell at this time.)

Song "Old Folks at Home," by Master Charlie Davison. Mr. George H. Wilson, President of the Engineers' Club of St. Paul, then responded to a call from Mr. Horton with some felicitous remarks.

Mr. Horton :—Gentlemen, we are all engineers here this evening, but when I call, as I do, for the greatest of our engineers, I am belittling none of the others. We will now listen to Mr. George S. Morison.

Mr. Morison :—Mr. President, I wish you had not called me up in that way, which makes me feel so much responsibility. I was very much gratified with the definition which our recent President gave of engineering, and I trust that I may apply that to the present occasion and say that as he defined engineering to be a thorough knowledge of the Western Society of Engineers, that there is no one here who wishes better for the future, the present and all the good of the Society than I do.

A great deal has been said about the Western Society, and there are a few things which I would like to call attention to. It is said that we have turbulent members. Turbulent members may be divided into two kinds. It is said that there are kickers in this world, and that there are croakers. The kicker makes a fuss and accomplishes his object, the croaker does nothing but find fault. I think that we may say that the turbulent members are all kickers. I do not think that we have many croakers. And I believe that their kicking has done a great deal of good. I believe that we did a great deal of good when we kicked at the Association of Engineering Societies, and I am very glad that the Association kicked back. We had a kicking match, and we are still in. I do not think it has done anybody any harm, and I think it has done all a great deal of good.

Now we have had a Committee, which, I understand from what has been said before, is no longer on the subject of reorganization. We are engineers, and as engineers we are supposed to understand mathematics, and to know that there is more than one dimension in this world. An account has been given of a strange race who lived in the land of one dimension and could only move in one direction. Now I think the Western Society made its great advance when it took its present name and its present character. That was nearly fifteen years ago. What was once the Civil Engineers' Club of the Northwest became the Western Society of Engineers; it discarded the word "civil," it merely said it was a Western Society, but not merely a Western Society of Civil Engineers. We have a national Society of Civil Engineers, another of Mechanical Engineers, another of Mining Engineers, and various others. All those Societies have extension in two dimensions, but they are both horizontal dimensions; they have an indefinite geographical extension, but a limited professional extension. I do not see why the Western Society cannot make its extension in the remaining dimension instead of trying to be a National Society. It cannot be the only society of the country, but it can be the leading society which embraces all kinds of engineering. That is its true method of extension, and that is the true meaning of the step it took when it reorganized

fifteen years ago, when it adopted its present name and when it began to become what it will very soon be.

Our past President has given us a pretty full statement of what this Society has done during the past year. It is a plain statement of dollars and cents. The Society, which was heavily in debt a year ago, has now a small surplus on hand. If, during the coming year, it does no better than it did last year, it will be able to pay all its current expenses, including its salaries, out of the receipts of the coming year. If it does that next year, as I fully expect it will, one year more will put it on the basis of paying its expenses out of what are strictly revenues, without in any way encroaching on admission fees or other things which by any possibility can be called capital.

It seems to me that we are doing well, and that we have simply to keep on as our past President and Secretary have helped us to do in the past, and as I believe our new President and Secretary will do in the future, to make the Society all that any of us really want it to be, the leading society of the West in every branch of engineering.

Judge Vincent, of the Civic Federation, was then called on by Mr. Horton, and, in the course of his remarks, said : "I know of no class in the community who are more thoughtful, who are more intelligent, than those who devote themselves to the profession of engineering, and it has been a matter of surprise and a matter of regret to me in the experiences which I have already related, that men who have such tremendous responsibility, who have interests of such magnitude intrusted to them, both as to their ability, their capacity and their honesty, are so poorly paid. I know of no professional men in the world who render so great and so valuable services at such small remuneration as does an engineer, and I hope the time will come when the laborer who is an engineer will be worthy of his hire, and that his brothers in the profession will not attempt to cut down his fees, but will do as they do in the law, sustain him in any fair, reasonable and liberal charge."

(Song, "The Fisherman," by Masters Davison and Soden.)

Mr. Horton then called upon Mr. Randolph, who spoke of the work under his charge, the Sanitary District Canal.

Mr. Horton then called on Mr. B. L. Crosby, of the Engineers' Club of St. Louis, who, in responding, said : I was very much interested in hearing how you manage your affairs over here, particularly as regards your library. Our St. Louis Club is much smaller than yours, and on account of our small membership we cannot pay salaries so as to have our library properly taken care of, hence it is of little use to us. During the hard times of the past year we have just about held our own as to membership, and we close the year with a small cash surplus and no debt.

Now that I have seen what your membership is, I think that if I had been a member of the Western Society I should have joined most heartily in your movements to withdraw from the Association of Engineering Societies. I think such a Society as yours is well able to take care of itself. (Applause.)

As smaller societies, we could not afford to publish our papers, and I think the Association, which was formed for that purpose, is a grand thing ; but whenever the St. Louis Club gets so it can stand on its own feet, as you evidently can here, if I am still a member of the Club, I shall advocate some such move as you attempted.

But I can say, on the part of the St. Louis Club, that we are very glad that you did not withdraw, and that you are still with us to help carry the load. . . .

We should be very glad to welcome any of you gentlemen at our meetings at any time you may be in St. Louis. I think we have a good club and I extend to you all a hearty welcome. (Applause.)

Remarks were also made by Professor Hatch, of the Armour Institute; Mr. Lorado Taft, of the Chicago Society of Artists; Mr. McCarthy, of the Builders' and Traders' Exchange, Mr. Lyman E. Cooley, and Capt. Robert W. Hunt, after which, owing to the lateness of the hour, the meeting adjourned.

THOS. APPLETON, *Secretary.*

APPENDICES.

I. Report of Secretary for the year 1894.
II. Report of Auditors (Financial Statement, 1894).
III. Report of Board of Managers Association of Engineering Societies.

APPENDIX I.

ANNUAL REPORT OF THE SECRETARY FOR THE YEAR 1894.

To the Western Society of Engineers:

At the beginning of my term of office the records showed the total membership of the Society to be 338

Since that time the losses have been:

By death, ...	5	
" resignation, ...	14	
Total losses, ...	19	
During the year there have been elected:		
Members, ...	63	
Associates, ...	25	
Juniors, ...	2	
Delinquents reinstated, ...	7	
Total additions, ...	97	
A net gain of		78

Making the total membership at present, including those recently elected, but not yet qualified, ... 416

Comprised of Members, ...	389
" " Associates, ...	25
" " Juniors, ...	2

Death has been an active agent in cutting down our membership list this year. The following have passed over to the great Majority:

Wm. H. Lotz,	who died	January 31st.
Abraham Gottlieb,	" "	February 9th.
Isaac Lincoln,	" "	March 13th.
Orlando H. Cheney,	" "	April 13th.
Joseph P. Card,	" "	October 22d.

During the existence of this Society many have lost their rights to membership through failure to pay dues. So far as the present Secretary has been able to ascertain, there is no record of any such person having been officially dropped from the rolls of the Society previous to January 3, 1894. At that time 96 names were dropped from the rolls of the Society for delinquency. In some cases this delinquency extended back several years; in others it was for the year 1894. Seven members, who were cut off a year ago, have paid up all arrearages and have been reinstated. The sum of the amounts due from delinquents of one year ago was $1,546.00. Of this amount, $92.50 has been collected this year.

The number of cases of delinquency for 1894, which will be reported to the next meeting of the Board of Directors is 14, with a total amount of $130.00.

The Society has held 13 meetings during the year, departing from the usual custom of omitting the July and August meetings. The attendance at meetings has varied from 30 to 91, averaging 55 per meeting.

The following papers have been read:

February 7th, "A Method of using High Explosives as a Means of Propulsion in Aërial Navigation," by Dr. Pynchon.

March 7th, "Original Construction of the Burlington Bridge," by Mr. C. H. Hudson, M. W. S. E.

April 4th, "Some Notes on the German Collective Exhibit of Engineering at the World's Columbian Exposition," by Mr. Charles J. Roney, M. W. S. E.

May 2d, "The New Tunnel of the West Chicago Street Railway under Chicago River near Van Buren Street," by Mr. Charles V. Weston, M. W. S. E.

June 6th, "Typhoid Fever and the Epidemic at Ironwood, Michigan," by Mr. E. A. Rudiger, M. W. S. E.

June 6th, "The Halsted Street Lift Bridge," by Mr. Samuel M. Rowe, M. W. S. E.

July 11th, "The Covered Reservoir of the Rockford Water Works," by Mr. Charles C. Stowell, M. W. S. E.

Same date, "The Corrosion of Iron Pipes by the Action of Electric Railway Currents," by Mr. D. C. Jackson, M. W. S. E.

August 1st, "A Prefatory Description of the Organization and Works of the Sanitary District of Chicago," by Mr. Isham Randolph, M. W. S. E.

September 19, "Strains and Deflections in Solid Bridge Floors," by Mr. Henry Goldmark, M. W. S. E.

October 3d, "Notes on a Broken Pinion Shaft," by Mr. Onward Bates, M.W.S.E.

October 3d, "General Hydraulics of the Chicago Main Drainage Channel," by Mr. T. T. Johnston, M. W. S. E.

November 7th, "Refrigeration by Carbon Dioxide," by Mr. E. F. Osborne, M. W. S. E.

December 5th, discussion of Mr. Goldmark's paper.

A total of thirteen papers, five of which have been printed in the JOURNAL OF THE ASSOCIATION OF ENGINEERING SOCIETIES.

All the meetings of the Society during the past year have been held in the Grand Pacific Hotel. Thanks to the generosity of Messrs. Drake, Parker & Co., proprietors, we have been provided with excellent accommodations without any expense whatever to the Society. This fact is apparent in the balance sheet for the year. In previous years the Society has paid from $10 to $15 per night for a meeting room.

The Secretary felt, on entering upon his duties, that in the past the social

phase had not been sufficiently developed, and so set to work, with the approval of the Board of Directors, to encourage this feature. It seemed desirable to provide opportunities for conversation, to afford some means for the members to become better acquainted with one another. With this end in view he arranged to keep the rooms of the Society open during a greater part of the business hours every week day, so that members might have an opportunity of meeting there. He also made the customary announcement, on notices of meetings, that those who could do so conveniently would sit down and eat together on the evening of the meeting, in the Grand Pacific Café. Many of those who have attended these informal lunches, which enabled them to while away the gap between office closing time and meeting time, have declared them to be an important and interesting adjunct of the formal meetings.

To still further develop the social features, excursions were arranged; the first to the Van Buren Street Tunnel and Power House of the West Chicago Street Railway, April 14th. This was attended by 75 members and guests.

The second excursion was a trip on the South Branch of the Chicago River, June 2d, to see the bridges at Canal and Halsted Streets, and the pumping works at Bridgeport. Transportation on this occasion was provided by Messrs. Shailer & Schniglau, members of the Western Society of Engineers, who kindly placed their steam barge "Burrows" at the disposal of the Society. Eighty members and guests enjoyed this trip.

Soon after this, a Committee on Excursions and Entertainments was appointed, whose active efforts have provided the Society with a series of pleasant excursions.

August 16th, an excursion on the lake was made by Steamer "Ivanhoe" to South Chicago and thence to Fort Sheridan. Ladies, guests and members, to the number of 140, enjoyed a most delightful trip.

September 8th, the first trip to the Main Channel of the Sanitary District of Chicago was made by a special train kindly furnished by the A. T. & S. F. Ry. Some 220 members and guests participated in this interesting excursion. The "all earth" sections at the Chicago end of the line, and the "all rock" sections near the other end, were visited. The party was most hospitably entertained at lunch by Messrs. Gahan & Bryne, Associate Members of the Western Society of Engineers, Contractors for Sections F. and G. of the Channel.

On the 6th of October, the second trip to the Sanitary District Channel was made. The Chicago & Alton R. R. kindly furnished a special train for the day. Some 258 members and guests enjoyed this trip. The sections located between those visited on the first trip to the Drainage Channel were inspected. Messrs. Griffith & McDermott, Associate Members of the Western Society of Engineers, Contractors for Section 1 of the Channel, provided an elaborate lunch for the party at their camp.

November 17th, a trip to South Chicago, taking in several of the important manufacturing industries of that thriving locality, was made by a party of 120 members and guests. The Baltimore & Ohio R. R. generously provided a special train for the convenience of the party.

The Society was fortunate in having fine weather on every one of these occasions, which proved most enjoyable and interesting. All of these trips have been made without any draft whatever on the Society's funds; even the printing of circulars and tickets and the postage for mailing the same, have been paid for by the committee. And, finally, the same committee has made all arrangements for the Annual Banquet now about to take place.

A midwinter excursion of the Society to New Orleans has been suggested, but up to the present date no arrangements for it have been perfected.

Early in the year the Secretary found that the work of cleaning, arranging and listing the long neglected library of the Society would occupy more time than he could spare. Hence he resigned the position of Librarian, and the Board of Directors appointed Mr. Charles J. Roney to the vacancy. To the energetic, painstaking and persistent efforts of Mr. Roney the Society is indebted for making our Library of use to the members. Probably very few of our members were aware of the extent and value of our collection of books, charts, etc., or realized how its contents could be built up at comparatively small cost. Of late the Library has been visited by many of the members in search of technical information, who have succeeded in finding on our shelves the desired data.

At the beginning of this year the Society was in debt. Although $308.28 of cash on hand was reported, $346.72 of the dues for 1894 had been expended for the payment of 1893 expenses by the former administration, and the $400 advanced by the Board of Directors was unpaid. During 1894 this loan has been paid, and $34 of 1893 bills, together with all the bills of 1894, leaving a small balance in the treasury, without touching any of the 1895 dues already collected. In brief $780.72 of old debts have been paid out of the receipts of 1894, and the Society does not owe a cent. This condition has been achieved through the generous responses of members to appeals for subscription funds for the Library and for the payment of services of Secretary and Librarian. For the Library Fund $312.68 has been collected, including revenue derived from sale of duplicates, $187.68 of which had been turned into the Treasury of the Society, with an unexpended balance of $83.18, and $125 is in the hands of the Library Committee.

For the Special Fund $897.40 has been collected, all of which has been expended.

The Secretary, in the early part of his term, cherished hopes of securing many more papers to be read before the Society than have appeared during the year. He had promises of a series of papers on Chicago High Building Construction, which are not yet ready. He thought that a paper on the Methods of Paying for Municipal Improvements by Special Assessment, with a thorough discussion of the subject, would be interesting and pertinent, but before he had secured any material this field was pre-empted by the Real Estate Board.

He has secured promises of papers enough to run through the meetings of the ensuing year, but he realizes that promise and performance are not synonymous terms.

The Society is to be congratulated on the increasing membership, the well-maintained attendance at meetings, the growing library, and its improved financial condition. Whatever efforts the Secretary might have made, these results could not have been accomplished without the hearty co-operation of the Board of Directors, the generous assistance of the Librarian, and the active efforts of many of the members. The Society is but a collective noun; it can only become what its members make it.

Respectfully submitted,

THOS. APPLETON, *Secretary.*

APPENDIX II.

Report of Auditors.

Financial Statement for 1894.

Receipts.

Collected by former Secretary	$655 00		
Expended by former Board in 1893	346 72		
		$308 28	
Delinquent dues		92 50	
Resident dues for 1894		1,950 00	
Non resident dues for 1894		613 15	
Entrance fees		405 00	
Hospitality Committee		167 28	
Sale of chairs		5 40	
Sale of Library Duplicates		7 90	
Subscription to Library Fund		12 50	
Subscription to Special Fund		897 40	
			$4,459 41
Non-resident dues for 1895		$67 50	
Resident dues for 1895		250 00	
			317 50
			$4,776 91

Disbursements.

Rent, Janitor, Light and Insurance	$576 36	
Postage and Postal Cards	213 25	
Stationery and Printing	296 61	
Stenographer and Typewriting	114 47	
Printing Proceedings	287 00	
Journal Association Engineering Societies	1,146 10	
Library	131 28	
Furniture and Shelving	53 14	
Deficiency on Banquet, January 3, 1894	67 00	
Repayment of Loan advanced by Directors in 1893	400 00	
Engrossing	30 00	
Express Charges and Incidentals	44 64	
Exchange Charges on Checks	3 15	
Salaries	999 99	
		$4,362 99
Cash Balance December 31, 1894		413 92
		$4,776 91

Thos. Appleton, *Secretary.*

The undersigned, forming the Auditing Committee of the Board of Directors, have examined the Secretary's books and compared the same with the Treasurer's books, and find the foregoing account to be correct and the payments supported by vouchers duly authorized by vote of the Directors.

C. L. Strobel,
Geo. S. Morison,
Robert W. Hunt.

APPENDIX III.

CHICAGO, JANUARY 1, 1895.

To the Western Society of Engineers:

GENTLEMEN:—In accordance with the requirements of the By-Laws, your representatives in the Board of Managers of the Association of Engineering Societies would respectfully report that at the beginning of the year 1894, Mr. J. C. Trautwine, Jr., was elected Secretary of the Board, and the JOURNAL OF THE ASSOCIATION has since been conducted by him. For a portion of the time the publication has been somewhat behind in its issue. With the close of the year, however, the issue is well up to date, the November number having been distributed some time near the 20th of December. This is as nearly on time as it is generally practicable for such a publication to be.

The character of the JOURNAL in its make-up, and the matter published, has in every respect been maintained, and in many ways improved.

Up to, and including the November number, there has been published during the year 676 pages of reading matter and 106 pages of proceedings of Societies, without counting the index notes. It is estimated by the Chairman of the Association that, not counting the index notes, but including the December number, there will be published for the year 820 pages, which is an increase of about thirty per cent. over the greatest amount of matter heretofore published by the Association during one year.

By a statement of expenditures made by the Secretary, which includes an estimate of the cost of the November and December numbers, the assessment of $3.00 per year will fall short of meeting the expenses of the Association by about $500, which will probably render a special assessment of 40 cents per member necessary to meet the year's expenditures. This additional expense is mainly due to the increased amount of matter published, and to the expensive nature of some of the illustrations, and to additional expenses incident to the change of the place of publication. It is hoped that another year will bring about results which will keep the expenditures within the usual limits.

The Board of Managers of the Association have under consideration measures which it is hoped will better meet the requirements of the Societies, particularly in the way of advanced papers. Though upon this subject, as upon others, no final decision has been reached, it is confidently expected that the needs of each Society belonging to the Association will be met.

Respectfully submitted,

BENEZETTE WILLIAMS,
THOS. APPLETON.

[The Report of the Managers on the part of the Western Society of Engineers in the Association of Engineering Societies was received too late to be read at the annual meeting, but is submitted herewith. Owing to the the absence of Mr. John Nichol from the State it has been impossible to get his signature to the report.—T. A.]

ERRATA.

In the Proceedings for 1894, as printed, the following corrections should be made:

No. 313, page 2, 8th line, for Alexander W. Gates, read Andrew W. Gates.

No. 320, page 2, 4th line from bottom, for E. A. Eckhart, read B. A. Eckhart; page 3, 6th line, for Braasche, read Braasch.

No. 322, page 2, 2d line, for Wm. C. Stearns, read Wm. H. Stearns; 3d line, for O. H. Vehmeyer, read C. H. Vehmeyer; 2d line in foot note, for Gaasche, read Gasche.

THOS. APPLETON, *Secretary.*

Boston Society of Civil Engineers.

FEBRUARY 20, 1895.—A regular meeting of the Society was held at its rooms, 36 Bromfield Street, Boston, at 7.50 o'clock P.M. Vice-President George F. Swain in the chair. Number of members and visitors present, including ladies, 118.

The record of the last meeting was read and approved.

Messrs. Samuel G. Armstrong, Henry W. Hayes, and Edward B. Stearns, were elected members of the Society.

The Chair announced the appointment, by the President, of Messrs. George A. Kimball and Austin B. Fletcher to serve as Tellers of Election at the annual meeting.

Attention was called by the Chair to the death of Franklin Darracott, an honorary member, who joined the Society in 1848; and, on motion, the President was requested to appoint a committee to prepare a memoir.

The Secretary read letters from the Boston Society of Architects and the Boston Architectural Club, expressing the thanks of these organizations for the invitation to attend the January meeting of this Society.

Mr. Cope Whitehouse, of New York, was then introduced and delivered a lecture on "The Proposed Reservoir for the Storage of the Surplus Flood-Waters of the Nile, and the Raiyan Drainage Canal." The lecture was profusely illustrated by lantern slides.

After passing a vote of thanks to Mr. Whitehouse for his interesting lecture, the Society adjourned.

S. E. TINKHAM, *Secretary.*

Civil Engineers' Society of St. Paul.

FEBRUARY 4, 1895.—A regular meeting of the Civil Engineers' Society of St. Paul was held at 8.30 P.M., President Stevens in the chair. Eleven members and one visitor in attendance.

The minutes of the previous meeting were read and approved.

The Secretary was authorized to print and distribute a list of members and to secure twenty-five copies of the Mr. Woodman's paper on Transition Curves.

The following report of the Committee on the Minnesota Topographical Survey was read and accepted:

REPORT ON TOPOGRAPHICAL SURVEY OF STATE OF MINNESOTA.

To the Civil Engineers' Society of St. Paul, Minn.:

Your Committee, having had under consideration the subject of the topographical survey of Minnesota, begs leave to report as follows:

The importance of such a survey is perhaps not so well understood and appreciated in our Western States as is the case in our Eastern States and in Europe, where the practical benefits of this form of public enterprise have long been enjoyed. A topographical survey of our State, that was rightly planned and executed, would contribute greatly to its development by suggesting many improvements connected with the subjects of transportation, good roads, water supply, hydraulic works, the draining of wet lands, the irrigation of dry lands, etc., and by furnishing at the same time, from maps, data for safe approximate estimates of the cost of such improvements, as is the fact in England, Germany, France and

Switzerland to-day, and even in Massachusetts and New York to a less reliable extent.

Your Committee would therefore advise that the Society express to the Regents of the State University its sense of the value and importance of the geodetic and topographic work thus far done in our State, and recommend that they continue the topographic work as heretofore, not only for the special economic value of the results, but also for the additional object of securing a continuance of the geodetic survey by the United States Coast and Geodetic Survey, which bureau is authorized to establish geodetic points in those States of the Union "which shall make requisite provision for their own topographic and geodetic surveys."

Your Committee would also advise that the Regents of the University be requested to have the topographic survey of the principal cities of the State and their vicinity, together with the principal rivers of the State, made in such detail as is suitable for a map on the scale of 1 : 20,000, which in our opinion is the smallest scale that will yield a map of adequate utility; also, that they continue the work through the agency of the College of Engineering of the University, and, as soon as circumstances will warrant, apply to the Legislature for special appropriations to increase the force employed and thus expedite the work, in order that its results may sooner be utilized by the general public.

Your committee would further report, that the topographical work recently done in this State by the United States Geological Survey, as placed before the public, is on the scale of one mile to the inch, and this scale appears to be adequate to the special objects of the Geological Survey. Although this survey is ably and economically conducted, and will, for a long time to come, be of sufficient accuracy and detail, and of great value for the greater part of this State, it does not secure the amount of detail in the particular districts before referred to, namely, the principal cities and rivers, to give its maps of those districts the general economic value they would possess if executed on the larger scale that we have proposed.

The accurate determination of geodetic points is the first requisite of a topographical survey. Following this, the filling in of details may be by rapid and ayproximate methods. As now organized, the United States Coast and Geodetic Survey is prepared to fix the geodetic points and the United States Geological Survey to fill in the details and publish the results. We consider it of prime importance to unite harmoniously these branches of the work, and to that end would urge our Senators and Representatives to forward the consolidation of the harmonious relations of these bureaus. Such a bureau should consist of men scientifically and technically fitted for the work, and appointed only under the strictest civil service rules.

Respectfully submitted,

E. E. Woodman,
G. L. Wilson,
H. E. Stevens,
K. E. Hilgard, *Chairman.*

St. Paul, Minn., February 4, 1895.

Mr. Woodman read from the December number of *Popular Science Monthly* a favorable comment, by Prof. Davis, of Harvard University, on the work of the U. S. Geological Survey.

The Librarian was requested to file for convenient reference the index and other sheets of said survey lately obtained for the Society by President Stevens and Mr. Wilson.

Mr. Armstrong reviewed and illustrated three U. S. Supreme Court decisions in the matter of riparian boundaries.

Mr. Münster gave his theory of the fact that two heavily loaded spans of the University Avenue bridge had remained standing after the post common to the two spans had been destroyed by a derailed cattle train.

C. L. ANNAN, *Secretary.*

Engineers' Club of St. Louis.

411TH MEETING, FEBRUARY 6, 1895.—President Russell called the Club to order at 8.10 P.M., at 1600 Lucas Place, there being twenty-six members and six visitors present. The minutes of the 410th meeting were read and approved The Executive Committee reported the doings of its 181st and 182d meetings. The committee had had a conference with a special committee from the Electric Club, and the two committees had agreed upon a plan for the future care of the Electric Club Library in the Engineers' Club Rooms, which plan both committees agreed to recommend to their respective clubs for acceptance. The Secretary reported that the Electric Club had ratified the report of its committee and that all that was lacking to complete the matter was the approval of the Engineers' Club.

On motion it was ordered that the plan be ratified and that the President be authorized to enter into an agreement with the proper officers of the Electric Club.

The President announced that he had added to the Eads' Monument Committee, Messrs. Julius Pitzman and T. H. Macklind.

The Secretary then read the following letter:

ST. LOUIS, January 30, 1895.

WM. H. BRYAN, ESQ., *Secretary Engineers' Club of St. Louis.*

DEAR SIR:—I have the honor to acknowledge the receipt of your favor of January 17th, in which you notify me that the Engineers' Club of St. Louis has elected me an honorary member, and request you to express to the members of the Club my high appreciation of the honor thereby conferred.

While I feel that the flattering terms in which the information is conveyed are hardly deserved, I may proudly affirm that during a professional career extending over half a century, I have always tried to do my share towards elevating the profession, and that of the work which I did in that direction in which I feel the greatest pride, has been the share taken by me in founding the Engineers' Club of St. Louis.

Although I cannot be a very active member of the Club, I have always taken a most earnest interest in its welfare, and hope that it will continue to grow in number of members and to enlarge its sphere of usefulness.

Very respectfully, HENRY FLAD.

On motion it was ordered that the letter be spread in full on the minutes of the Club.

The further discussion of Mr. B. L. Crosby's paper upon the St. Louis Extension of the St. Louis, Keokuk & Northwestern R. R., read December 19th, was taken up. Mr. Crosby exhibited a number of lantern slides, showing foundation work on the piers of the Sioux City, Nebraska City, Rulo and Bellefontaine bridges across the Missouri River, and the Alton and Memphis bridges across the Mississippi. The Morison clay hoist and sand pump were described in detail, as were also the details of the caisson work, and the use and construction of air-locks. Figures were given showing the cost of deep foundations at different places.

The hour being late, it was on motion ordered that the reading of Mr. Curtis' paper on "A System of Water Purification" be deferred until the next meeting, February 20th.

Adjourned. WILLIAM H. BRYAN, *Secretary*.

412TH MEETING, FEBRUARY 20, 1895.—President Russell called the Club to order at 8.20 P.M., at 1600 Lucas Place, with twenty-one members and eleven visitors present. The minutes of the 411th meeting were read and approved. There being no regular or miscellaneous business, Mr. J. H. Curtis then addressed the Club on "A System of Water Purification," which he had developed, with special reference to the removal of organic matter.

He had been experimenting for over two years and had discovered that where sand filters were not submerged, but where the water was allowed to drip upon the sand bed, just as rain falls upon the earth, particles of air followed the drops of water through the sand, making the most complete aëration possible. The author's experiments, however, had only been conducted on a small scale, and he was unable to give any figures as to the actual amount of purification, or capacity of filter beds, based upon actual service.

Colonel E. D. Meier then read a translation of a paper by Professor August Ritter, of Germany, on "The Mechanics of Soaring Flights." The paper was intended to prove mathematically that where wind currents varied in velocity, it was possible for a bird to soar or rise without doing work itself. The paper claimed that repeated observations of soaring birds showed that there was no motion of the wings, and that very delicate observations of wind velocities indicate wide fluctuations.

In the discussion of the paper, Professor Johnson stated that this matter had already been presented in this country by Professor Langley, and that he, Professor Johnson, had answered it very fully in *Aëronautics*. He denied absolutely the premises on which the paper was based, viz.: that a bird did not move its wings or feathers, and that there were such frequent and regular fluctuations of wind velocities. He also showed that even admitting the premises to be true, and placing actual values in the formulæ, the wind velocity remaining available for supporting the bird was entirely too small for that purpose.

Professor Kinealy stated that some years ago Dr. Todd had read a paper before the Academy of Science in this city, showing that the tail or primary feathers of the buzzard were articulated in a way permitting of a motion similar to sculling, and that there were well-developed muscles connected with these feathers. These were found only in soaring birds, and they give the primary feathers a very rapid motion, which it was thought was capable of sustaining the bird. Mr. Crosby and Mr. Wheeler also took part in the discussion, the general trend of which was to the effect that the soaring was accomplished by some motion of the bird's feathers, invisible to the naked eye.

Adjourned. WILLIAM H. BRYAN, *Secretary*.

Montana Society of Civil Engineers.

FEBRUARY 9, 1895.—The regular meeting of the Montana Society of Civil Engineers was held at the Society rooms, in the Denver Block. The meeting was called to order by President Keerl. There were present the following members

Messrs. Keerl, Haven, Kelly, Goodale, Relf, Cumming, Heuley, Smith and Hovey; also several visiting engineers. Wyllys A. Hedges, member of the House of Representatives from Fergus County, was also present.

The application of Charles A. Molson for membership, recommended by Messrs Keerl, Heuley and Goodall, having been approved by the Trustees, was read and the Secretary was directed to send out to the members a letter ballot for the same. Ballots for admission to membership were then canvassed by Messrs. Kelly and Relf, tellers. Upon the announcement of the result, the President announced the election of Daniel P. Mumbrue, Charles H. Palmer, Charles W. Mead, Maurice S. Parker and Charles M. Allen as members of the Society.

A. E. Cumming, of the Committee on County Surveyor and Road Laws, reported that both bills, substantially as adopted by the annual meeting, had been introduced in both houses of the legislature, and that several meetings of the legislative committees had been held, but that no final action had yet been taken. It was voted that the committee be continued and requested to take all necessary steps to urge the passage of the two measures.

The regular order of business was suspended, and the Secretary read a paper prepared by E. H. Beckler, honorary member of the Society, upon the location and construction of the United Verde and Pacific Railway, which was constructed under his direction as chief engineer for the Hon. William A. Clark, of Butte, and completed December 1, 1894. The paper was listened to with much interest by all present. It was then referred to the Board of Trustees, who directed the Secretary to arrange for its publication at an early date in the Journal of the Association of Engineering Societies. On motion of Mr. Goodall, a vote of thanks was given to Mr. Beckler for his paper, and the Secretary was directed to inform him that it would be published as soon as possible.

Letters were read from Col. Joseph T. Dodge and others commending the action of the Society in its efforts to obtain some action by the legislature giving a legal definition of a miner's inch. The colonel says: "Your effort is most praiseworthy and is in behalf of good morals as well as social peace and good will"; also commending the action of the Society in beginning a movement for the more "economical expenditure of the road tax of Montana."

The regular order of business was then resumed, and Mr. Cumming, of the Committee on Water Measurement, reported that the proposed act, adopted by the annual meeting, had been presented to both branches of the legislature; that it had passed the Senate and that it is now before the Committee on Irrigation of the House; that the Society's Committee, the President and other members of the Society had several times met with the House Committee, who had expressed a desire to have A. M. Ryon, who made an able address to the Committee of the Whole of the Senate, to meet with them some evening of the coming week to explain more in detail some parts of the act. After a long discussion by all the members present, it was voted that the President be requested to communicate with Mr. Ryon asking him to meet the committee on the evening of February 12th, and to say that his traveling expenses would be paid by the Society.

Mr. Goodall, the committee to whom was referred the annual address of ex-President Haven, reported that he had looked at rooms for permanent headquarters for the Society and recommended room No. 8, Denver Block, for such purpose, and that the "Secretary's desk and other property of the Society be moved to that room as soon as practicable." The report in relation to permanent quarters for the Society was accepted.

It was voted to thank Mr. Cumming and also Mr. Keerl for the use of their offices for the purposes of the Society up to the present time.

The Committee on the DeLacy Memorial was given further time until next meeting to make their report.

F. J. SMITH, *Secretary.*

Civil Engineers' Club of Cleveland.

CASE LIBRARY, CLEVELAND, OHIO, February 12, 1895.—The meeting was called to order at 7.50 by the President. Forty-eight members and visitors were present.

The record of the meeting held on January 8th was read and approved.

The application of Joseph R. Oldham for Active Membership, Axel Hugo Petterson for Corresponding Membership, and Geo. H. Bowler for Associate Membership, were read.

A letter was read from H. F. Coleman, transmitting his resignation as a Corresponding Member.

A letter was read from Mr. Peter Neff, Jr., transmitting his resignation from Active Membership.

The Nominating Committee reported as follows:

Your committee appointed at the last meeting, January 8th, to prepare a list of officers for the ensuing year, begs leave to report the following list of candidates:

President, Augustus Mordecai.
Vice-President, C. W. Wason.
Secretary, F. A. Coburn.
Treasurer, J. C. Wallace.
Librarian, James Ritchie.
First Director, Walter Miller.
Second Director, John L. Culley.

Respectfully submitted,

A. H. PORTER, *Chairman.*

Mr. Richardson moved that a committee be appointed to make any necessary arrangements in the way of fixing up the portion of the Library room which will hereafter be occupied by the Club. Amended by Mr. Searles to refer the matter to the Executive Board. Amendment and original motion were both adopted.

Prof. Howe moved the appointment of a committee of seven to make arrangements for the Annual Banquet. The President appointed on this committee Messrs. A. H. Porter, J. N. Richardson, Prof. C. S. Howe, Frank C. Osborn, M. W. Kingsley, James Ritchie and Alex. E. Brown.

Mr. John L. Culley then gave a brief account of the Cincinnati meeting of the Ohio Society of Surveyors and Civil Engineers.

The tellers, Prof. D. C. Miller and Mr. Harry S. Nelson, announced the result of the ballot on Amendments of Constitution as follows:

Total number of envelopes received		46
Number rejected for non-endorsement	2	
Number rejected not entitled to vote	2	4
Number of legal ballots cast		42

	Yes.	No.
Article V, Section 1	34	8
" V, " 2	35	7
" IX, " 10	37	5

The Amendments were therefore declared adopted.

Col. Jared A. Smith then presented, informally, a paper entitled "Engineering of Crib Construction as Applied to Harbor Improvements," which was discussed by Messrs. Culley, C. H. Strong, Richardson, Porter, Geo. M. Ried, Barber, Rawson, Searles and Howe.

President Swasey then gave a brief account of the Appian Way, visited by him on his late trip abroad.

Meeting adjourned at 10 P.M. FRANK C. OSBORN, *Secretary.*

Association of Engineering Societies.

Vol. XIV. **March, 1895.** No. 3.

PROCEEDINGS.

Western Society of Engineers.

The 324th meeting of the society was held in Science Hall, Armour Institute, Chicago, Wednesday evening, February 6, 1895.

Previous to the meeting twenty-one members and guests took dinner together at the Grand Pacific Cafe.

The members and their guests were received at Armour Institute by the Faculty, and under the courteous guidance of the students of the Technical College, visited the various departments of the Institute, after which the meeting was called to order at 8 o'clock, in Science Hall, President Horace E. Horton in the chair and 150 members and guests present.

On motion, the routine business of the evening was dispensed with, and President Gunsaulus, of Armour Institute, welcomed the society to the Institute in the following brief address:

"I have asked your president to allow me just a word in the name of my associates in Armour Institute to convey to you our hearty welcome and to rejoice with those who do rejoice even in the midst of this inclement weather to-night.

"When I was asked to say just a word on behalf of the gentlemen who compose the Faculty of the Institute, who have to do with the science of engineering in its various branches, I felt that it was quite out of my line, and when some gentleman, coming up on the car with me to-night, said: 'I suppose you will certainly be able to welcome the engineers with heartiness, even though it be a very cold evening,' I thought that the expectation was a little large, owing to the fact that I know so little about the subject. I remember that when I came into the Institute and was elaborately discussing witn a trustee of my church some of the things that we had put in, the names of machines that I had most recently learned, and therefore was very anxious to pronounce in his hearing, he said to me, 'Look here, Doc, do you know the difference between a dynamo and a motor?' I confess I felt a little puzzled with his question, and was hardly able to answer.

"But I have learned just enough, gentlemen, to appreciate your presence here in Armour Institute, and I assure you that we do understand the

immense value to us of your coming to us to-night, what it means to our students, and what it may mean to all the future of our Institute work.

"It is not necessary, I am sure, for even a minister to be a mechanical or an electrical engineer in order to be conversant with the fact that without practical men close to us we cannot do any thorough work with the young men who give their lives and welfare in our charge.

"I have often been reminded, in meetings of this sort, of the necessities that we used to find in theological seminaries. Now and then a minister who was in the midst of his work came into the seminary, and, being a spiritual engineer, as you men are mostly mechanical, civil or electrical engineers, we found ourselves in the presence of facts that we learned entirely too little about in our common work, as the days went by. It is our effort, here in Armour Institute, to unite the ideal and the practical, to begin with the great facts of science and to come closer to the earth with all its practical problems, and I assure you that the presence of so many men who are actively engaged in engineering gives spinal column and atmosphere to our work such as we could obtain nowhere else.

"Before I took hold of this Institute I was very anxious to find men who would share with me the feeling that nothing is so ideal that it may not be most practical, and that the most scientific training is, after all, ultimately the most practical training in these lines. And I have been fortunate enough, I think, to associate together in this institution men who share these hopes. We are anxious indeed that our young men should be in the closest possible touch with those who are doing, in the world of the present, the things that they are to do in the world of the future.

"This is distinctly a great gift and help to us, and we thank you to-night for your presence, and hope that you will always feel that Armour Institute is at your disposal, every room, every book in our library, that we may give to the Western Society of Engineers for its pleasure, as you shall give to us of your experience and information, is at your command." (Applause.)

The two papers for the evening—Description of the Work and Methods of Construction on the Brighton and Summit Divisions, respectively, of the Chicago Sanitary Drainage Canal—were then read by the authors, Messrs. Alexander E. Kastl and E. R. Shnable, the engineers in charge on those divisions.

The papers were illustrated by a large number of very fine lantern views of the work, and of the machinery and appliances in use on these divisions of the canal. These views were especially prepared by the Institute, without cost to the society, and were projected by a high power electric lantern, adding very much to the interest of the meeting. The papers are to be published in the "Journal."

There being no discussion of the papers, the meeting adjourned.

The company then repaired to the Department of Domestic Arts and were served with a light lunch, dispersing at a late hour. The first meeting of the society at Armour Institute was an unqualified success, despite the stormy weather.

At a meeting of the Board of Directors, held February 5, 1895, the applications of the following named gentlemen for membership in the society were received and placed on file:

As Members—George Marshall Ames, Grand Rapids, Mich.; A. M. Feldman, Chicago; Charles Linneus Gould, Chicago; Stephen French Hoge, Romeoville, Ill.; John McCalman, Fenton, Mich.; Lauren Bronson Merriam, De Kalb, Ill.; James H. Travis, Chicago; Robert Bruce Wilcox, Chicago.

CHARLES J. RONEY, Secretary.

325th Meeting, March 6, 1895.—The 325th meeting of the society was held in the society's new rooms, 1737 Monadnock Block, Chicago, at 8 P.M., March 6, 1895, President Horton in the chair and about 125 members and guests present.

The reading of the minutes of the previous meeting was dispensed with, President Horton, for the Board of Directors, reporting progress in the management of the affairs of the society, without going into details.

The Secretary reported as follows:

At the meeting of the Board of Directors held March 5, 1895, the following named gentlemen were elected to membership:

As Members—George Marshall Ames, Grand Rapids, Mich.; Charles Linneus Gould and A. M. Feldman, Chicago; Stephen French Hoge, Romeoville, Ill.; John McCalman, Fenton, Mich.; Lauren Bronson Merriam, De Kalb, Ill.; James H. Travis and Robert Bruce Wilcox, Chicago.

The following applications for membership were received and placed on file:

As Members—George M. Basford, Chicago; C. V. Brainard, Kampsville, Ill.; William S. Dawley and Nicholas D. Pound, Chicago; Leonard Sewall Smith, Madison, Wis.; George E. Waldo and Edward Dana Wickes, Chicago.*

As Associates—George Horace Bryant and Charles F. Quincy, both of Chicago.

Bills to the amount of $188.93 were approved and ordered paid.

The Treasurer reported funds on deposit, March 1, $1214.52.

Mr. Gerber then read the following report of the Committee on Excursions and Entertainments:

Chicago, March 6, 1895.

Western Society of Engineers.

Gentlemen: The Committee on Excursions and Entertainments for 1894, having finished its work with the ending of the banquet held at the annual meeting, wishes to submit the following report:

The committee arranged for the following entertainments:

August 16—Excursion by steamer on lake to ship yards of the Chicago Ship Building Company on Calumet River, and from there, in the afternoon, to Fort Sheridan and return. This excursion was participated in by 140 persons, members and their families, and from expressions of members from time to time, the committee hopes that it was considered a success.

The next excursion was on the 8th of September to the Drainage Canal by train over the Atchison, Topeka and Santa Fe R. R. The "all earth" sections at the Chicago end of the line, and the "all rock" sections near the other end of the line were visited. The railroad company furnished a special train free of charge and, by the courtesy of Messrs. Gahan & Byrne, a lunch was provided. The entire excursion was without expense to the members, 220 participated in this excursion.

The third excursion was also to the Drainage Canal, the work inspected on this occasion being between Summit and Willow Springs. A special train was this time furnished by the Chicago and Alton R. R. and lunch by Messrs. Griffiths & McDermott. This excursion was also without expense to members. There were 258 present.

The fourth excursion was a trip to the works of the Illinois Steel Company, Iroquis Furnace Company, Chicago Ship Building Company and Morden Frog & Crossing Company. The Baltimore and Ohio R. R. fur-

* At a meeting of the Board of Directors, held March 19, the application of Mr. Charles F. White for membership was received and placed on file.

nished a special train; lunch was provided by the committee, a charge of fifty cents being made to the members 120 persons were present.

The fifth entertainment arranged for by your committee was the annual banquet, at which there were 111 members and guests.

When your committee was appointed, it was instructed that it should make its arrangements without any expense to the society. Invitations were liberally issued to prominent people of the city for the last three excursions, and a considerable number to the annual banquet. The expense occasioned by these invitations was borne by the committee and defrayed from amounts paid by the members. The committee has the pleasure, therefore, to report to the society that in its management it has not drawn a single cent from the treasury of the society, the committee having this day reimbursed the society for the expense of engrossing five sets of resolutions presented to the railroad companies and the contracting firms who so courteously furnished us with trains and lunches.

The committee also takes pleasure in being able to say that they are not individually out of pocket on account of any of these entertainments. We hope that the work of the committee has been satisfactory to the society, and we now request that the committee be discharged.

The committee wishes to take this opportunity to thank Mr. Appleton, who kindly consented to act as secretary to the committee and pulled the laboring oar.

H. E. HORTON,
E. GERBER,
FERD HALL,
J. J. REYNOLDS.
R. SHAILER, Committee.

The report was accepted, and the committee was discharged with the thanks of the society.

Mr. Strobel read the following report of the Committee on Quarters:*

To the Western Society of Engineers.

The Committee on Quarters respectfully reports that it has secured accommodations for the society on the seventeenth floor of the Monadnock Block, rooms 1736 to 1739, both inclusive.

The Monadnock Block is a first-class office building, fire proof.

A three years' lease has been taken, running from May 1 of this year, with the privilege of possession free of rent until May 1.

The space secured measures 1000 square feet, and is about one-third greater than the space occupied by the society in the Lakeside Building. The rent for this larger space is about the same.

The rate at which these accommodations were secured is about one-third of that usual for like accommodations in first-class office buildings.

The rooms face towards the East, giving a fine view of the lake. These quarters are as free from smoke and dirt as can reasonably be expected in the business quarter of the city.

The rooms are now occupied by the society.

C. L. STROBEL,
T. APPLETON.
CHAS. J. RONEY, Committee.

Chicago, February 6, 1895.

* This report was prepared for presentation at the meeting of February 6, but all routine business of that meeting was dispensed with, and the reading of papers followed.

The report of the committee was accepted and the committee was discharged.

It was voted that the chair appoint a committee of five members as a Committee on Excursions and Entertainments for the year 1895.

It was voted that the Committee on Library, of the past year, be continued. The committee are Messrs. O. Chanute, Fred Davis, John Lundie, Henry M. Sperry and Charles J. Roney.

President Horton announced a special meeting at Armour Institute for March 20, and addressed a few words to the guests of the evening in regard to the society.

The business meeting then adjourned, and the company engaged in conversation and partook of the bountiful lunch provided by a special committee of the Board of Directors, dispersing at a late hour after a thoroughly enjoyable and sociable gathering.

On Saturday afternoon, March 16, 1895, on invitation of Mr. Samuel G. Artingstall, City Engineer, about 75 members and guests visited the new Van Buren street rolling-lift bridge. Every opportunity was afforded for a study of this novel bridge, representatives of the City Engineer's office, and of the contractors, explaining the construction and working of the bridge, which was repeatedly operated for the pleasure of the company. The Metropolitan West Side Elevated Railway Bridge was also visited by invitation of Mr. William Hughes, Assistant Chief Engineer, who, with his assistants, gave much interesting information regarding this bridge.

A special meeting of the society was held at Armour Institute, on Wednesday evening, March 20, 1895, at 8 o'clock, President Horton in the chair and 86 members and guests present.

The President announced as the Committee on Excursions and Entertainments: Messrs. Thomas Appleton, E. Gerber, James J. Reynolds, Ralph Modjeski and George P. Nichols.

Mr. Warren S. Roberts, City Engineer of Bridges, then read his paper —"The Van Buren Street Rolling-lift Bridge," the paper being illustrated by many lantern views. A lantern view of the Tower Bridge of London was then shown, and Mr. Strobel presented some interesting notes in regard to this bridge.

A written discussion of Mr. Roberts' paper, by Mr. W. W. Curtis, was read by Mr. Lincoln Bush, and was followed by oral discussion by Messrs. Goldmark, Hasbrouck, Strobel, Roberts, Bush, Appleton, Nichols, Johnston, Liljencrantz and President Horton, after which the meeting adjourned.

CHARLES J. RONEY, Secretary.

Boston Society of Civil Engineers.

ANNUAL DINNER, March 12, 1895.—The thirteenth annual dinner of the society was served at the Exchange Club, Boston, at 6.30 o'clock P. M. One hundred and sixty-three members and guests were present. President William E. McClintock sat at the head of the table, and the following gentlemen were present as guests of the society; Mr. George S. Morison, president of the American Society of Civil Engineers; Mr. Frank A. Hill, secretary of the State Board of Education; Mr. George G. Crocker, chairman of the Boston Transit Commission; Mr. Osborne Howes, of the Commission on Greater Boston; Mr. Woodward Emery, chairman of the Massachusetts Harbor and Land Commission; Mr. George A. Perkins, chairman of the Massachusetts Highway Commission; Colonel H. G. Prout, editor of the "Railroad Gazette;" the Rev. Thomas Van Ness, Mr.

G. A. Stacey, president, and Mr. J. C. Whitney, secretary of the New England Water-Works Association; Mr. W. L. Dickinson, chairman of the Massachusetts Highway Association; Mr. F. M. Curtis, secretary of the New England Railroad Club, and Mr. F. M. Wakefield, secretary of the Boston Architectural Club.

President McClintock, after a few words of congratulation to the members on the work of the society during the year, introduced Mr. Morison, who humorously admitted that the American Society was the junior of the Boston Society by a few years. "But," he added, "so also is the United States of America the junior of the Commonwealth of Massachusetts by 125 years." He contrasted the local with the national society, and went on to define the characters of the two, the chief distinction between them being, he thought, clearly indicated by their names. He spoke of the convention of the American Society which was held in Boston in June, 1878, and was glad to say that the next convention would be held in Boston in June. At that time the members would wish to see what had been accomplished in Boston during those 17 years. "No city in the country," said he, "holds the advanced position that Boston holds in respect to the development of a water system, a sewerage system and a park system."

The next speaker was Mr. Hill, of the Board of Education, who referred to the numerous "brain Saharas" which all professions must struggle with—the prejudice and ignorance everywhere found—and lauded the wonderful triumphs of the engineering profession. Mr. Crocker spoke in a humorous vein, declining to discuss in detail the subject of rapid transit. His general idea of rapid transit was to start on time, to travel as rapidly as possible and to stop easily.

Mr. Howes narrated pleasantly how his little boy had puzzled him with the question: "If Mr. So-and-So is a civil engineer what is an uncivil engineer?" He then offered an explanation of the use of the word "civil" in that connection. "Civil" is a part of the word "civilization," and civil engineering is the forerunner and promoter of modern civilization.

Colonel Prout, Mr. Emery and the Rev. Mr. Van Ness closed the speaking of the evening.

ANNUAL MEETING, March 20, 1895.—The annual meeting of the Boston Society of Civil Engineers was held at its rooms, 36 Bromfield street, Boston, at 7.45 o'clock P. M., President William E. McClintock in the chair. Eighty-nine members and visitors present.

The record of the last meeting was read and approved.

Messrs. William M. Bailey, Arthur Bartlett, Herbert E. Gage, Nathan C. Grover, George H. Hamlin, Henry G. Hunter, Henry A. Nash, Jr., Arthur J. Ober, Arthur G. Pierce and Bertrand T. Wheeler were elected members of the society.

On motion of Mr. Folsom it was voted, "That the thanks of the society be given to our fellow-member, Mr. William H. Bradley, for his very interesting gift of a portrait of the late E. Sylvester Chesbrough, one of the founders and one of the earliest officers of our society, and president of the American Society of Civil Engineers."

On motion of Mr. Manley the sum of $25.00 was added to the appropriation for the incidental expenses of the last annual dinner.

The annual report of the Board of Government was read by the secretary and accepted.

The annual reports of the secretary and the treasurer were read by these officers and accepted.

The annual report of the Committee on Excursions was read by its chairman, Mr. Winslow, and accepted.

The annual report of the Committee on the Library was read by the librarian and accepted.

Mr. Doane, for the Committee on Permanent Quarters, made a verbal report, explaining what had been done by the committee during the year, and it was accepted.

The Committee on Weights and Measures was given until the next meeting to submit its report.

On motion of Mr. Stearns it was voted to refer to the Board of Government, with full powers, the questions of continuing the several special committees and of the selection of the members thereof.

The secretary read a communication from a Committee on Standard Gauges for Thickness, of the American Society of Mechanical Engineers, requesting the co-operation of this society in the effort to abandon the system of arbitrary gauges and to secure the adoption of a decimal system giving the actual thicknesses and diameters of the pieces. After a short discussion it was voted to refer the communication to the Board of Government, to report back to the society what action was desirable.

Mr. George A. Carpenter presented the report of the committee appointed to prepare a memoir of Mr. Lincoln G. Heywood, and it was read and accepted.

Mr. A. F. Noyes presented the report of the committee to prepare a memoir of Mr. Hiram Nevons, which was also read and accepted.

Mr. Kimball, for the tellers, submitted the result of the letter-ballot for officers.

There being no election for president and librarian by letter-ballot, the meeting proceeded to choose these officers from the two candidates having the highest number of letter-ballots.

As the result of the letter-ballots and choice of the meeting, the president announced the following officers elected:—

President, ALBERT F. NOYES.
Vice-president (for two years) DEXTER BRACKETT.
Secretary, S. EVERETT TINKHAM.
Treasurer, EDWARD W. HOWE.
Librarian, FRANK L. LOCKE.
Director(for two years), RICHARD A. HALE.

The president called attention to the fact that at the close of the meeting, one of our members, Mr. Henry Manley, would retire from the Board of Government after fifteen years of continuous service, and spoke in very complimentary terms of the faithful manner in which Mr. Manley had served the society as treasurer, president and director. In response to the hearty applause which followed the remarks of the president, Mr. Manley thanked the members for this expression of their appreciation of his efforts in the interest of the society. He spoke of the pleasure his connection with the society had always given him, and of the pride he took in its prosperity, and closed by extending to the society his best wishes for its continued success.

President William E. McClintock then delivered his annual address as follows:

TO THE MEMBERS OF THE BOSTON SOCIETY:

The most casual observer cannot fail to note the great changes in the profession of the civil engineer since the organization of the Boston Society 47 years ago. In the early years of our society, railroads were in their infancy, street railways were not deemed of sufficient importance to call for the services of an engineer, sanitation and water supply were prac-

tically unknown factors, electricity was but a plaything, its real commercial value not even being dreamed of by the most visionary of dreamers, road building was one of the undiscovered arts, as far as this country was concerned, iron and steel were used in the most primitive manner, and were hardly thought of in connection with bridges or buildings, and a thousand and one things which seem to us but everyday facts were then in the great to be. There was not seen in those days the bustle of today. The few people who traveled were in no hurry, and, if they were, it availed them nothing. Mails were sent and received, but a few days more or less in their transmission were taken as natural and unavoidable delays, and caused no comment. Freight was in many instances delivered weeks after it was expected, the telegraph was nothing more than a lively infant, and the man who dared suggest the possibility of sending messages across the ocean would have been considered a fit subject for a lunatic asylum, while he who turned his face to the wall and repeated his "Hello," "Yes," "No," "All right," with the claim that he was holding conversation with parties hundreds of miles away, might have been almost burned at the stake as one beingin league with the powers of darkness.

Our houses and business blocks were simple and plain, with but little artistic skill in plan or execution. Our streets were roughly paved and but dimly lighted at night. Our houses and public buildings were lighted for the most part with the tallow candle or the whale oil lamp, which tended to deepen the gloom of night. As one looks about him and stops to think, he will gradually realize the great changes which have taken place during the few years which have elapsed since the founding of this society, and the civil engineer cannot fail to have a certain amount of pride when he feels that to the members of this society and of kindred societies in different parts of the world has fallen the duty of planning and directing the works which have wrought such a change in the social conditions of the world. Ours is a work which demands a steady hand and an active brain, a power to plan and an ability to change the original plans to meet the unexpected, which is sure to happen in engineering works; and, to be successful, an engineer must keep pace with the times and not repeat a blunder which has at any time been shown to be such.

History and law, mechanics and mathematics, tact and patience, are all needed, if one would succeed, and when one does succeed it is a great surprise to see on what slight foundation his success is based. If called upon to give the first requisite of a civil engineer, I should name honesty. He is not counsel to argue for his client, but rather judge and jury to decide what is right, regardless of persons, and, looked at in this light, he must have a clear head, and an honest, unbiased judgment. This brings up the question whether an honest, unbiased judgment, in connection with engineering skill and experience, is a merchantable commodity, to be sold to the highest bidder. Unquestionably it is not, and the engineer who countenances such action injures not only himself but likewise the whole profession. The astronomer recognizes the personal equation of his fellow observers, and by careful comparison reduces their observations to one standard. The engineer who sells his judgment to the highest bidder must sooner or later establish a personal equation of honesty, and competition will inevitably lower the standard as it will demand that the study be made at as low a cost of labor as possible, while the expression "It is good enough for the money" will surely be thought, if it is not expressed.

I am glad the Boston Society is broad and liberal in its requirements as to membership admission. The local societies are the home and school, the means of closer fellowship and intermingling of ideas. It is by means of these societies that the old jealousies have been largely broken down,

and a brotherly feeling has taken their place, so that each engineer feels to rejoice with the successes of his fellow-engineer. I say largely broken down, as it is with regret that we still observe isolated cases where one attempts to elevate himself by pulling his brother down. If we expect to place engineering among the learned professions, education and ability must be accompanied by dignity, and the policy of advertising, except by card, or that of writing and visiting parties with the purpose of soliciting the privilege of planning and supervising large works must be discontinued, and such practices should be frowned down by every engineer, as would be the case in the practice of law or medicine. Possibly it may be a misfortune that the civil engineer has no stated code of ethics, or schedule of prices. As a result it often happens that roving committees find one engineer who unconsciously gives figures lower than another for performing the same work, and thus unwittingly places himself in competition. This difference in price may result from increased facilities on the one hand, or it may arise from a desire to obtain the work at all hazards, and at any price. If the difference results from the cause first named, no fault can be found; but if, on the contrary, the last named reason applies, it not only demeans the guilty party, but it also belittles the profession and tends to bring the engineer into disrepute.

The society has just passed through a very successful year, the membership having been increased by the addition of thirty-two new names, bringing the total up to 354. The regular meetings have beeen well attended, the papers have been carefully prepared, and of unusual interest. The excursions to local points of interest, or to works in progress, have been of value to the many who attended them, and the informal suppers before the regular monthly meetings have increased in popularity, and are a great factor in bringing our members together and making them better acquainted, one with the other. The weekly informal meetings in the library, with descriptions and discussions of work being done, have been so well attended that the capacity of the room has been sorely taxed. and the question of enlarged headquarters has been unexpectedly and forcibly brought before the society. The attendance at these informal talks has been nearly double the attendance at the regular monthly meetings of fifteen years ago, and their continuance in more commodious quarters should be the early aim of the society. Many of our members do not realize that the permanent fund of the society is growing quite rapidly, and that within the past fourteen years we have succeeded in saving. from our regular income, over $6000. This sum may seem small, but one has only to look at the Franklin fund. which, without any increment other than the interest, increased from about $5000 to $375,000 in a little over one hundred years, and he will see that with the honest conscientious attention which our fund receives from our treasurer, we may expect it to increase so that the younger members may reasonably expect to carry on the work of the society in a home of its own. The kindly forethought of one of our members in subscribing a liberal amount for the establishment of a fund for permanent headquarters, has opened up a new line of thought in this direction, and I trust that the beginning thus made will spur others on in the same direction, and induce them also to build for the future.

The general depression of business has more or less affected engineering works, although many important schemes have been started, or reported on. during the year, and some extensive works have been brought to a successful termination. Notably amongst the works which have been started may be mentioned the Commonwealth's action in regard to parks and State Highways. Amongst the reports which have been made reference may be made to the Charles River dam and the Metropolitan

Water Supply. The activity in steam railroad work has mostly been confined to additions and improvements, such as can be seen at the new Union Station, Boston. The elimination of grade crossings at Mystic Wharf, Boston; the Roxbury crossing, the Brockton crossings and other like work. The electric railways have ceased to be a purely city institution. They are now reaching out in every direction, and are sure to be a competitor with the steam railroads. In the laying out of these railroads the engineer should have in mind the perplexing problem of grade crossings, as illustrated by the steam railroads, and he should do all in his power to prevent, if possible, a repetition of this great evil. The planning and execution of both public and private work are being more and more entrusted to the engineer. Almost every city, and some of the larger towns, have a regularly elected engineer to look after the public works.

No city or town would for a moment consider the sewerage or water problem without a careful study and report by a competent engineer, and he is not only called upon to plan work, but he is also required to advise on ways and means, and in various other directions. The old fallacy that an engineer cannot sit as a member of a deliberative commission seems to have been broken down, in our State at least, by the appointment of four members of our society on as many different and important commissions. We must bear in mind that we are what we make ourselves, and it remains for us to act in such a conservative, careful and dignified manner as will demand the confidence of our clients and the respect of the public at large.

In closing I wish to thank you as a society for the great honor you have conferred upon me by electing me to serve as your president during the period just past. I can assure you that I deem it one of the greatest honor of my life, and as I step back into the ranks, it will be with renewed effort to do everything within my power to bring honor and success to our society.

At the close of the formal address, Mr. McClintock had thrown upon the screen a large number of lantern views showing the work done by the Massachusetts Highway Commission in the construction of State roads. Views were also shown of the roads and other objects of interest in Bermuda which Mr. McClintock had recently visited.

(Adjourned).

S. E. TINKHAM,
Secretary.

Annual Report of the Board of Government for the Year 1894-1895.

In compliance with the provisions of the Constitution, the Board of Government submits the following as its annual report for the year ending March 20, 1895:

We congratulate the members of the Society upon the very prosperous year which is now closed. A larger number of names has been added to our list of members than in any previous year, the attendance at the regular meetings has been greater, our annual dinner brought together more of our members than were ever assembled before, and our financial condition was never better.

During the year ten regular meetings have been held, and the thirteeth annual dinner of the Society took place on March 12, 1895. The total attendance at the regular meetings was 896, an average of 90, the smallest attendance at any meeting being 40 and the largest 121. The attendance at the annual dinner was 163, a gain of nearly one- third over the largest attendance at any previous dinner.

The following papers and discussions have been given at the regular meetings:

March, 1894. New Formula for Calculating the Flow of Water in Pipes and Channels, by W. E. Foss. Account of Driven Wells in Lowell, by George Bowers.

April, 1894. Street Grades and In tersections, by William B. Fuller. Account of Welding Electrically the Tracks of the West End Street Railway, by A. L. Plimpton.

May, 1894. Improvements of the Charles River, by F. P. Stearns, with discussion (illustrated).

June, 1894. Cement Joints for Sewer Pipes, by F. C. Coffin. Bicycle Track at Waltham, by W. E. McClintock.

September, 1894. Testing Materials at Massachusetts Institute of Technology, by Gaetano Lanza.

October, 1894. Cableways, by Spencer Miller (illustrated).

November, 1894. European Water Supplies, by Allen Hazen. Lake Vyrnwy Water Supply, by T. M. Drown.

December, 1894. Memoir of C. W. S. Seymour. Abolition of Grade Crossings, by J. W. Rollins, Jr.

January, 1895. Use of Steel in Large Buildings, by C. T. Purdy (illustrated).

February, 1895. Proposed Reservoirs for the Storage of the Flood Waters of the Nile, by Cope Whitehouse (illustrated).

At the last annual meeting the total membership of the Society was 322, of which 315 were members, 5 honorary members and 2 associates. During the past year we have lost 9 members—5 by death, 1 by resignation, 1 by transfer to the Engineer's Club of St. Louis and 2 by forfeiture for non-payment of dues. There have been added to the Society during the year 41 members—37 by election, and 4 who had resigned or forfeited membership, have been reinstated. The net gain in membership has been therefore 32.

The present membership of the Society consists of 2 associates, 4 honorary members and 348 members, a total of 354. This number entitles the Society to a fourth member on the Board of Managers of the Association of Engineering Societies.

The record of deaths for the year among our members is as follows: Hiram Nevons, who died May 27, 1894; Forrest L. Libbey, who died July 21, 1894; Phineas Ball, who died December 19, 1894, and Lincoln C. Haywood, who died January 12, 1895. We have also lost one of our honorary members, Franklin Darracott, who joined the Society at its organization in 1848 and died January 24, 1895.

The plan inaugurated last year of holding informal meetings in our library on other Wednesday evenings than those assigned to the regular monthly meetings, has been continued during the winter months. The only difficulty experienced so far in arranging these meetings has been in the way of accommodations. At some of these meetings the attendance has exceeded thirty persons, and our library is wholly inadequate for such a gathering. As a matter of record, a list of the informal meetings is here given, with the subjects discussed.

January 31, 1894. Sewerage of Newton, by H. D. Woods.

February, 1894. Work of the Metropolitan Sewerage Commission, by Charles H. Swan.

February 28, 1894. Work of the Boston Sewer Department, by E. S. Dorr.

March 14, 1894. Work at Dam 6, Boston Water Works, by N. S. Brock.

March 28, 1894. Brookline Water Works, by F. F. Forbes.

April 4, 1894. Construction Work of the Boston and Albany Railroad, by William Parker.

April 11, 1894. Boston Public Parks, by E. W. Howe.

April 25, 1894. Details and Methods of Work on Massachusetts State Survey, by E. E. Pierce.

May 2, 1894. Oxidation of Structural Iron by Electrolytic and Other Means, by J. H. Stanwood.

May 9, 1894. Work of the Harbor and Land Commissioners, by F. W. Hodgdon.

November 28, 1894. City Engineering at Duluth, Minn., by William B. Fuller.

December 5, 1894. Coinage, Weights, Measures and Trigonometric Tables, by Fred Brooks.

December 12, 1894. Recent Water Works Construction, by F. L. Fuller.

January 2, 1895. The Present Method of Laying Out Streets in Boston, by F. O. Whitney and F. M. Miner.

January 9, 1895. Graphical Computation as Applied to Engineering Problems, by Freeman C. Coffin.

January 16, 1895. Notes on Power Production, by Robert S. Hale.

January 30, 1895. Lighthouse Foundations, by Edward P. Adams.

February 6. 1895. Sewer Construction in Malden, by G. A. Wetherbee.

February 13, 1895. Municipal Work in Brookline and Vicinity, by A. H. French.

February 27, 1895. Coal Handling Appliances for Supplying Locomotives, by J. P. Snow.

March 6, 1895. Municipal Work in Cambridge, by L. M. Hastings.

The report of the Treasurer shows a net gain of $791.42 in the funds of the Society during the past year.

One of our ex-presidents, Mr. Desmond Fitzgerald, has subscribed a liberal amount to form the nucleus of a fund for permanent headquarters. This act demands more than an acknowledgment with thanks, as it opens up a new field of action. Without any recommendation as to methods, the Board of Government would suggest that the Society, at an early date, take some definite action towards adding to this fund.

Respectfully submitted, for the Board of Government,

WILLIAM E. McCLINTOCK,
President.

Abstract of the Treasurer's and Secretary's Reports for the Financial Year 1894-1895.

CURRENT FUND.

RECEIPTS.

Dues of new members	$181.50
Dues of resident members for 1893-94, 2 at $7	14.00
Dues of resident members for 1894-95, 244 at $7	1708.00
Dues of non-resident members for 1893-94	5.00
Dues of non-resident members for 1894-95, 70 at $4	280.00
Dues of non-resident members for 1894-95	1.00
Dues of non-resident members for 1895-96, 3 at $4	12.00
Sales of Journal	4.30

Rent of office	150.00	
Interest on deposits	1.43	
Cash at beginning of year	131.68	
		$2,488.91

EXPENDITURES.

Association of Engineering Societies	$1150.75	
Rent	500.00	
Printing, postage and stationery	292.49	
Periodicals and binding	98.38	
Expenses at meetings, stenographer and lantern	48.00	
Expenses at special meeting	6.25	
Secretary's salary	200.00	
Gas	4.10	
Annual dinner of 1894	32.00	
Cash on hand	156.94	
		$2,488.91

PERMANENT FUND.

RECEIPTS.

Thirty-seven entrance fees	$370.00	
Interest and dividends	161.32	
Share of Merchants' Co-operative Bank, retired	88.54	
World's Fair Headquarters Fund	54.40	
Subscription to Building Fund	50.00	
Payment of real estate mortgage	800.00	
Cash at beginning of year	27.55	
		$1,551.81

EXPENDITURES.

Due in shares in Merchants' Co-operative Bank	$300.00	
New shares in Merchants' Co-operative Bank	61.42	
Cash on hand, uninvested	1190.39	
		$1,551.81

SCHEDULE OF FUNDS OF SOCIETY ON MARCH 20, 1895.

One Republican Valley Railroad bond (par value)	$600.00	
Nine shares C., B. and Q. R. R. stock (par value)	900.00	
Mortgage on real estate	1000.00	
Twenty-five shares Merchants' Co-operative Bank	2175.17	
Cash on hand, Permanent Fund	1190.39	
Cash on hand, Current Fund	156.94	
		$6,022.50
Schedule presented last annual meeting		5,231.08
Increase during the year		$791.42

Report of the Committee on the Library.

There seems to be but little that the Library Committee can say in the way of a report, but it may be well to mention one or two matters: First, to emphasize the fact of the space for books being so cramped, there being insufficient room even to place the books upon the shelves, to say nothing of arranging them in proper form. It is utterly impossible to find room for the new accessions under the present arrangements; and,

while temporary expedients might be adopted, it would hardly be wise to spend much money in that way when more permanent quarters are in view.

The number of books has increased more rapidly this year than in any previous year, and especially is this true of the more valuable publications of the day.

It is to be hoped, and we earnestly request, that any member of the Society who directly or indirectly publishes anything having the slightest engineering interest, or has any such publications of others brought to his notice, will see that a copy is placed on the shelves of the Society, or, where unable to obtain them themselves, will notify either the Librarian or the Secretary in regard to the matter, thus assisting materially to increase the value of the library.

The use of the library has changed but little during the past year, members finding it rather difficult to get desired information from the shelves on account of the crowded quarters. However, with proper surroundings and a full catalogue, there is no doubt that its use can be greatly extended.

The present system of taking out books is exceedingly faulty, and, but for the thoughtfulness of the members, there would be a large number lost annually. It seems impossible to change this, as we are now situated, but it is earnestly hoped that in the near future a catalogue and a better system of distribution can be obtained.

Until new or more permanent quarters have been procured the Committee cannot make any specific recommendations regarding equipment or operation, but they earnestly hope that no stone will be left unturned to provide proper accommodations at as early a date as possible.

For the Committee on the Library.

HENRY F. BRYANT,
Librarian.

March 20, 1895.

Report of the Excursion Committee.

The report of the Excursion Committee of the Boston Society of Civil Engineers is herewith submitted.

During the year the Committee has provided seven excursions and will, according to custom, provide one more, that for April, 1895. The trip for April, 1894, provided by the previous Committee, was to the works of the Curtis-Davis Soap Company, in Cambridge, and owing to the fact that it immediately preceded a holiday, there were but four persons present. In May a trip was taken to the new Leavitt Pump, at Chestnut Hill, Brighton, also to the force main connecting the pump with the reservoir. Thirty members were present. The June excursion was omitted on account of the New England Water Works Convention.

In September a trip was taken to the new dam, No. 5, now in process of construction by the city of Boston, and there were 52 present.

In October the Deer Island outfall sewer of the Metropolitan System was visited, also the Moon Island Works of the Boston Sewerage System. Seventy-five attended this excursion.

In November a visit was made to various points of interest in Lowell, 42 being present.

In December the excursion was omitted, and in January the East Boston Tunnel of the Boston, Revere Beach and Lynn Railroad was inspected by 42 members.

The most popular trip of the year was made in February to the

Charlestown Navy Yard, to see especially the new ram Katahdin. Other points of interest in the Yard were visited, 110 members and friends being present.

In March the garbage reduction works of the New England Construction Company, on Gibson street, Dorchester, were visited, 55 members present.

The Committee desires to express to many of our members its appreciation of the many courtesies extended and the co-operation cheerfully given in order that our excursions might be successful.

For the Committee,

FREDERIC I. WINSLOW,
Chairman.

March 20, 1895.

HIRAM NEVONS.

A MEMOIR.

By R. C. P. Coggeshall, Albert F. Noyes and Dexter Brackett, Committee of the Boston Society of Civil Engineers.

(Read March 20, 1895.)

Hiram Nevons was born at New Gloucester, Me., April 5th, 1836. His father was a farmer and he lived at home until he was sixteen years old, when he went to Portland to learn the carpenter's trade. The next year we find him employed by a firm of ship builders at Freeport, Me., where he remained four years. He then came to Boston and entered the service of Gore, Rose & Co., municipal and railroad contractors, who soon placed him in charge of their paving contracts with the city of Cambridge. Although but twenty-one years of age, he had already demonstrated a rare ability in the leading and management of workmen, and his services were deeply appreciated by his employers. Owing to the panic of 1857, business soon became very much depressed, and during the following winter we find Mr. Nevons at Mobile, Ala., where, in company with two other Northern men, he contracted to do a large amount of work on a mail steamer then building there. The following spring he returned to Cambridge and re-entered the service of his former employers, Gore, Rose & Co., remaining continuously with them until the spring of 1862, when, under the pressure of war time, nearly all work on municipal improvements ceased.

He then returned to Freeport, Me., where, in September, 1862, he enlisted in the Twenty-fifth Regiment of Maine Volunteers. He remained in the service until the regiment was mustered out, in July, 1864. The following three years he was engaged in ship building at Yarmouth and Freeport, Me., and at Cleveland, O. In September, 1867, he returned to Cambridge and followed the business of paving for the next ten years, eight in the employ of Gore & Co. and the remainder on his own account.

On May 8, 1877, he was unanimously chosen to be superintendent of the Cambridge Water Works, which position he ably filled until the day of his death.

It was with great reluctance that Mr. Nevons accepted this position, feeling that he could not command the requisite training in hydraulic engineering, but no mistake in the selection of a superintendent was made by the Cambridge Water Board, for he applied himself with characteristic energy and persistency to his new duties and to studies connected therewith, and soon became well informed upon all matters pertaining to water works construction and maintenance, and his opinions commanded the respect of his large circle of acquaintance among water works officials.

During the seventeen years covered by his administration he occupied an important part in the development of the many improvements which have been made to the Cambridge Water System. The additional supply from Stony Brook has been constructed and Fresh Pond has been deepened in its shallow parts. Its shores have been riprapped, and girdled by a wide and attractive drive, and its neighborhood has been converted into a fine park. Other extensive improvements were being made at the time of Mr. Nevons' death. Through all these years Mr. Nevons has modestly attended to his various duties in the most faithful manner. He always proved himself to be a highly satisfactory leader of the men under his charge, and has always retained the confidence of his fellow citizens.

He married an estimable lady of Freeport, Me., in 1859, by whom he had four children, all of whom are living.

He was one of the most widely known members of the Water Works fraternity of New England, and was a member of many societies. Among these may be named in the Masonic Fraternity, the Grand Army of the Republic, the Boston Society of Civil Engineers, the American and the New England Water Works Associations, the Citizens' Trade Union, the Cambridge Club, and others. In all of these he took an active interest and was an honored and beloved member.

He died at his home in Cambridge, Mass., on May 17, 1894, after several weeks of great suffering.

A fitting testimonial to his work and character was offered in the form of resolutions passed by the Cambridge City Council, and the Cambridge Water Board.

He joined the Boston Society of Civil Engineers June 19, 1889, and while, on account of his exacting official duties, he was not permitted to take an active part in its work, he took a great personal interest in the work of the Society and continued his membership during his life. As a man and true christian citizen, he was held in high esteem by all who knew him; as a friend and associate, he was an intelligent, genial, agreeable and thoroughly companionable man.

LINCOLN C. HEYWOOD.

A MEMOIR.

By George A. Carpenter and Morris Knowles, Committee of the Boston Society of Civil Engineers.

(Read March 20, 1895.)

Lincoln Crawford Heywood, youngest son of George and Mary (Reed) Crawford, was born in Pawtucket, R. I., September 29, 1868. Upon the death of his mother he went to live with his aunt, Mrs. Charles Heywood, whose husband was then superintendent of the Boston and Fitchburg Railroad. His early education was received in the public schools of Boston, which city was the home of his adopted parents.

After the death of Mr. Charles Heywood, in 1884, the family removed to Pawtucket, R. I., and the course of study was continued there in the High School. The young man was graduated with the class of 1886, and, with a number of his classmates, entered Brown University in the fall, remaining as a member of the class of 1890 for three years. During this time he prepared himself for that branch of work in which he was ever after deeply interested, and by diligent and conscientious labors he was able in 1889 to enter the third-year class of the Massachusetts Institute of

Technology. He was graduated with this class in 1891, receiving the degree of Bachelor of Science in the Department of Civil Engineering. The title of his graduating thesis was: "A Plan for Widening the Stone Highway Bridge at Pawtucket, R. I.," and this, together with his other school work, showed the careful and painstaking habits which have characterized all of his later efforts.

Upon leaving school Mr. Heywood was engaged by the Interstate Street Railway Company as their engineer, and in accordance with his plans and under his supervision their large system was built. In July, 1893, he severed his connection with the Interstate Company to accept the position of engineer of the town of Lincoln, R. I., which had been tendered him. He was re-elected in 1894, and held this office at the time of his death.

One of the most important problems encountered in this last position was the design of a sewerage system for a certain section of the town which had long been in need of sewers, but up to this time many difficulties had arisen to prevent their construction. The plan suggested by Mr. Heywood proposed intermittent filtration as the method of disposal. This received the approval of the town authorities, and money was appropriated for the construction of the system, upon which work he was engaged at the time of his last sickness. He desired as well to bring the sewers of the different sections of the town into one complete and harmonious system, and had taken steps to reach this beneficial result.

Mr. Heywood was also much interested in, and had worked upon, a set of assessor's maps of the town. It was his intention to establish and locate all important points by a system of co-ordinates referred to and connected with the United States Coast and Geodetic Survey.

On December 15, 1892, Mr. Heywood was united in marriage to Edith, only daughter of Bela P. Clapp, of Pawtucket, and beside his wife a little daughter remains to mourn his loss.

He was associated with the Delta Upsilon Fraternity, being a charter member of the Brown University Chapter. He was also a member of the Union Lodge, No. 10, A. F. and A. M., and of the Pawtucket Royal Arch, Chapter No. 4.

Mr. Heywood was taken ill the last of December with that dread disease, typhoid fever, which he, in common with many other engineers, through the agency of pure water supplies and proper sewerage systems, had been striving to render less dangerous to the community and less likely to become epidemic in thickly settled districts. He died January 12 1895, being mourned by a loving family and a large circle of friends.

Mr. Heywood became a member of the Boston Society of Civil Engineers May 20, 1894. Although cut off at an early age, he yet leaves behind an example of earnest, thorough and conscientious devotion to the work of the profession, an example by which we may all profit.

GEORGE A. CARPENTER,
MORRIS KNOWLES,
Committee.

Civil Engineers' Club of Cleveland.

ANNUAL MEETING.

CASE LIBRARY, March 12, 1895.—The meeting was called to order at 8 o'clock P. M. by the President. Forty-three members and visitors were present.

The record of the meeting held on February 12 was read and approved.

A verbal report from the Banquet Committee was presented by Mr. Richardson, and also by Professor Howe. The annual reports of the secretary and treasurer were then read, and it was moved and carried that the reports be accepted and placed on file. The annual report of the librarian was then presented, which was also accepted and ordered placed on file. The librarian, in concluding his report, offered the following resolution, which was unanimously adopted:

"Resolved, That the Civil Engineers' Club of Cleveland, wishing to signify their appreciation of the labors of Chairman J. B. Johnson and Secretary J. C. Trautwine in advancing the interests of the Association of Engineering Societies, and in improving the journal of the association, hereby extend to the gentlemen named, a unanimous vote of thanks."

A unanimous vote of thanks was tendered Mr. Ambrose Swasey for the beautiful photograph, representing the bridge and castle of St. Angelo, which he had presented to the club.

A report from the Program Committee was presented by the chairman, E. C. Cooke, which report was accepted and ordered placed on file.

President Swasey then read the annual address, entitled "The Specialist in Engineering." See appendix.

The Secretary then read the reports of the tellers appointed to canvass the ballot for members and officers. Joseph Rogers Oldham elected to active membership. George Herbert Bowler elected to associate membership. Axel Hugo Petterson elected to corresponding membership.

The following were elected to serve as officers for the coming year:

For president, Augustus Mordecai.
For vice-president, Charles W. Wason.
For secretary, F. A. Coburn.
For treasurer, Jome C. Wallace.
For librarian, James Ritchie.
For first director, Walter Miller.
For second director, John L. Culley.

After some short speeches by the newly-elected officers, it was moved by Mr. Mordecai that a vote of thanks be tendered the retiring officers of the club. The motion was unanimously carried.

President Swasey then extended his thanks to the vice-president and secretary of the club, as well as the other officers, for the assistance and support which they had given him throughout his term as president.

The meeting adjourned at 9.30 o'clock.

FRANK C. OSBORN,
Secretary.

APPENDIX.

THE SPECIALIST IN ENGINEERING.

ANNUAL ADDRESS OF PRESIDENT AMBROSE SWASEY.

The many difficult and seemingly insurmountable problems in engineering and construction, which have been solved in ancient and modern times, serve as guide posts clearly pointing to the most direct road by which the engineer of to-day may reach his destination. Yet there are many new problems constantly presenting themselves, whose perplexing complications call forth the engineer's thorough knowledge of what has been done, and his skill and ability to devise new ways and means for meeting these new conditions. The many crowded technical and scientific schools throughout this country, where thousands of our brightest young men are

being educated and trained in the various departments, show conclusively that America is awake to the fact that more will be demanded of the rising generation, and that they will be required to undertake the most difficult engineering works. Those who, when young, had not these privileges, but were obliged to study early and late in order to gain the knowledge which is comparatively so easily acquired in these modern schools, so splendidly equipped with every appliance for demonstrating the practical as well as the theoretical side of engineering, can truly appreciate the great advantage they are to the young men who honestly desire a scientific education.

And to what grander and nobler purpose can wealth be devoted than to such practical institutions as Peter Cooper and hundreds of others throughout this country have endowed and equipped? Now, more than ever before, men realize that money thus donated is not spent, but transferred and transformed into active minds, trained in their especial lines of work, upon whom the engineering and scientific achievements of the future must depend.

The engineering societies throughout the country are to the engineers of to-day what the technical schools are to the future. The members of these societies, being men of experience and of similar professions, realize the great benefits derived from attending the sessions, where they may come in contact with those who are working in the same lines, and, although busy men, they travel to distant points of the country in order that they may take part in the discussion of subjects in which they are especially interested, or listen to the advice and experience of others. The increasing numbers and influence of these societies, whose transactions represent the most modern thought and practice, testify to their great value in the education and advancement of the engineer.

The few societies, which, like our own, have among their memberships civil, mechanical and electrical engineers, architects and scientists, and before which are presented papers upon the correlated subjects peculiar to these several classes, provide, for their members, a variety of interest to all. At these meetings we learn of the many types of bridges in use, of the great steamships and of the engines that propel them, of the long and difficult railroad tunnels and trestles, of the generators and transmitters of electrical energy, and of the construction of our great modern buildings; or the scientist tells us of his investigations, of the thought and care that had to be taken at every step of the process, of the minute and subtile quantities with which he had to deal, and he then gives us the result of his research, which was gained only after years of patient toil. Few, perhaps, fully understand the difficulties which he encountered, or appreciate the benefit of the result to the cause of science, yet all are intensely interested in his work and may learn the lesson of accuracy, of the necessity of attention to the smallest detail, and, most important of all, of perseverance. And so with all the subjects that are presented at these meetings. We may learn from each much that will aid us, and we cannot fail to see that the greatest achievments have been won by those who have devoted themselves to a special line of work.

When we visit the interesting city of Florence and see that wonderful statue of David, the admiration of the world, chiselled by Michael Angelo's own hands from an abandoned block of marble, and then enter the Sistine Chapel at Rome and look with amazement at his ceiling frescoes, which are said to excel even those of Raphael, and then retrace our steps and stand beneath the great dome of St. Peter's, which he also designed, and which is acknowledged to be one of the grandest examples of architecture, we feel that to one man at least have been given especial powers by which he

could excel in these great arts, sculpture, painting, architecture and engineering. But the world waited many years for a Michael Angelo, and it has not yet seen another. Few can expect to accomplish what he did, for when we call to mind the works of the great painters, Raphael, Titian and Rubens, or of the sculptors, Canova and Thorwaldsen, or of the architects, Giotto and Brunelleschi, we find that these men won distinction in a single art, although, no doubt, they were ambitious to excel in others.

When we visit the city of Antwerp and study the lines and proportions of the arch or gateway designed by Rubens, and then turn to his most famous paintings in the Cathedral near by, we can but wish that he had continued to use his brush, and had left the designing of the arch to such an architect as he who, one hundred years before,constructed the beautiful lacework tower of that Cathedral. And the same principle holds true in our day. The men who have been foremost in science, in art, in architecture, and in engineering, are those who have given their life work to a single calling or profession.

The beautiful grounds and buildings of the Columbian Exposition formed a noted example of the work of specialists; architects, civil, hydraulic, landscape, mechanical, electrical engineers, scientists, sculptors and artists, each having experience and a thorough knowledge of his own particular department, like trained soldiers, under the direction of an efficient leader, went forward and completed this great work, the result of which we all know. It could not have been otherwise, because it was not the work of one, but the work of many. The grand municipal and mercantile buildings which are now erected so quickly in our great cities, are composite, not only because they are built of different materials, but because they are built by different professions. The architect studies the requirements, lays out the plan, and gives to it expression. The scientist tests the steel for the phosphorus and carbon, and determines the strength and quality of the cement. The civil engineer constructs the foundations and designs the trusses, while the mechanical and electrical engineers attend to the problems of heating, ventilating and lighting, and that of carrying its occupants from floor to floor.

Although a Hunt may design the palatial residences of Newport or give character and grand proportion to the Administration Building, whose dome glittered both by day and by night, yet he called to his assistance an engineer to work out the details of construction, and a sculptor to model the statuary that adorned it. This magnificent structure, when completed, was their combined work, yet it added new laurels to the fame of the architect, and to that of the sculptor and engineer as well. This shows only that the greater the success of the undertaking, the greater the credit to all who take part in the work, and that the architect or engineer who attempts to do the work of others, in order that he may take the entire credit to himself, generally fails in all.

Apparently some are not yet aware that the day of the Universal Engineer, who claims to have a thorough knowledge of all branches of engineering, is past. The high character of the work that is being done throughout the country shows conclusively that it is not the Universal Engineer, but the experienced specialist, who has charge of it. This division of labor in engineering and construction means, more public improvements, more convenient and architectural buildings, better equipped railroads, safer and faster ships, machinery of improved design, and bridges not only substantial, but architectural. In the new Tower Bridge of London, the iron work which sustains the loads is encased in most exquisite stonework for architectural effect, after the manner of our best build-

ings of to-day. This bridge has been severely criticised because of its cost and because it does not represent upon the outside its true construction, yet no doubt, in years to come, it will be looked upon as one of the finest examples of architectural engineering of this age.

We have already done much in this country towards making our public works more ornamental. The beautiful Washington Bridge, so much admired by all, shows our high appreciation of the artistic as well as the useful, and in the future more will be required of the engineer in this direction than ever before.

The old millwright, of the first half of this century, had to construct alone the dam across the river, to hew the logs, and erect the mill, to shape the teeth of the wooden cog wheels, to turn the bearings of the square shafting, and to pick the flinty stones for grinding the grain. If he, like Rip Van Winkle, could now awake, he would find that not only the mountain trees have grown taller and the familiar faces gone, but that his work has been divided between many professions, and that the progress of civilization has so leavened these that many of them have in turn been subdivided, and that, as a consequence, the leaky wooden dam has been replaced by one of solid masonry, the huge creaking overshot water wheel has been taken down in order that the spinning steel turbine might do its work, and that there is left of the mill or machinery but little that he can recognize. Even the old millstones have been taken out and used for steps, while the grain is passing with lightning speed between fluted iron rollers. He finds, in addition to these changes, that, in order to meet the ever-increasing demands of our modern civilization, larger and swifter rivers have been controlled, until the great Niagara has been harnessed to furnish power for heat, light and manufacturing, not only within the sound of its own roar, but by means of threads of copper to great cities many miles away. No wonder the world seems strange to him and that he wishes to return to sleep. Should he awake in the middle of the twentieth century he would find that even greater things have been accomplished by the engineers now being trained in our technical schools, that the forces of nature have been more and more utilized until the energy of the beautiful cascades of the distant mountains has been carried into the homes of the people for their convenience and comfort, and, so long as civilization lasts, new and difficult problems will constantly arise to tax the skill of the engineer.

Civil Engineers' Society of St. Paul.

MARCH 4, 1895.—A regular meeting of the Civil Engineers' Society of St. Paul was held at 8.30 P. M. Present, 15 members and 5 visitors, President Stevens in the chair. Minutes of previous meeting read and approved. The following committee on standard wire gauges was appointed by the President: Mr. Crosby, Mr. Toltz, Mr. Merryman, Mr. Lyon and Mr. Hogeland. The question of the consolidation of the various U. S. surveys was referred to the Committee on Minnesota State Survey and Mr. Powell.

Mr. Truesdell read a paper entitled "The First Engineer." Hero, in his opinion, was the man to be honored with this title. Hero was the first to formulate and practically apply, 200 years B. C., the principles of geometry and mechanics. This pioneer instructor in practical science invented land surveying and leveling, and perfected innumerable engines of war and other constructions. An enthusiastic vote of thanks was accorded Mr. Truesdell.

Mr. Crosby displayed a number of drawings illustrating the solution of some of the problems met with during the construction of the 40-ton crane just completed by his company for the Mare Island Navy Yard.

C. L. ANNAN, Secretary.

Engineers' Club of St. Louis.

413TH MEETING, March 6, 1895.—Vice-President Ockerson called the club to order at 1600 Lucas Place, at 8.20 P. M.; twenty-three members and nineteen visitors present.

The minutes of the 412th meeting were read and approved, as corrected. The Executive Committee reported the doings of its 183d and 184th meetings, announcing the resignation of Mr. T. L. Condron.

The resignation of Mr. J. N. Judson, as librarian, was read, and, on motion, accepted. Ordered, on motion, that the matters of nominations for the office of librarian, and compensation for his services, be referred to the Library Committee, with request for a report at the next meeting.

The secretary read a letter from the chairman of the American Society of Mechanical Engineers' Committee on Standard Gauges for Thickness, requesting the appointment of a committee to co-operate with them in the matter. The secretary also read a report embodying the action of that committee, in conjunction with a committee of the American Railway Master Mechanics' Association. On motion it was ordered that a committee of three be appointed on this subject. The chair appointed Messrs. E. D.Meier, J. Kinealy and W. H. Bryan.

Prof. J. B. Johnson then addressed the club on the subject of "Wood Structure," explaining in detail the characteristics of the various woods commonly found in the markets,and the methods and appliances used in testing their strength. The lecture was illustrated by a large number of stereopticon views showing cross-sections which brought out plainly the characteristics of each wood. It was shown that the strength of the wood depends upon the proportion of solid to porous matter, the former being due to the rapid spring growth, and the latter to the slower summer and fall growth. He also showed that the strength was reduced as the percentage of moisture increased. He considered this the real explanation of Prof. Lanza's statement that large pieces of timber were weaker than small ones, as the laboratory tests had shown no difference in this respect. Messrs. Crosby, Kinealy, Moore, Wheeler and Winslow participated in the discussion.

Adjourned.

WILLIAM H. BRYAN, Secretary.

414TH MEETING, March 20, 1895.—President Russell called the club to order at 8.15 P. M. at 1600 Lucas Place. Twenty-five members and nine visitors present. The minutes of the 413th meeting were read and approved. The Executive Committee reported the doings of its 185th meeting. The following applications for membership were announced: George B. Leighton, vice-president Kansas and Texas Coal Co., and Joseph Ramsey, Jr., general manager Terminal Railroad Association.

Mr. J. A. Laird reported for the Committee on Library the nomination of Mr. W. A. Layman for librarian. He also reported progress in the matter of re-arranging the library. Mr. Laird's resignation as chairman had been accepted, and Mr. Julius Baier had been elected as his successor.

The secretary read the following report:

Mr. S. Bent Russell, C. E.

President The Engineers' Club, St. Louis, Mo.:

Dear Sir: Your Committee on Standard Gauges for Thickness of Metals beg leave to report as follows:

A letter from the American Society of Mechanical Engineers, dated February 21, 1895, to the Engineers' Club, asks us to co-operate with their society in the matter of recommending a gauge system based on actual thickness and diameters and state it in a decimal system. Your committee are unanimous in the opinion that the old arbitrary gauges now in use are apt to lead to confusion, and the course recommended by the joint committee of the American Society of Mechanical Engineers and the Railway Master Mechanics' Association is the right way out of the difficulty. It is absolutely necessary in mechanics and in business that standards should be plain, easily understood and of as wide acceptance as possible. Since it is not at present feasible to introduce the French system of measures used all over the Continent of Europe, in our practice, there can be no doubt that giving thicknesses in thousandths of the inch is the best practical method of designation.

Your committee therefore propose the following resolution:

Resolved, That the St. Louis Engineers' Club recommends to its members and urges upon all persons using a gauge system to abandon the use of arbitrary gauges and to give the actual thicknesses and diameters in thousandths of the inch.

Resolved. That the Secretary of the club be instructed to send copies of this resolution to the secretaries of the other associated societies, requesting them to concur, and to the secretary of the American Society of Mechanical Engineers.

In view of the fact that the American Society of Mechanical Engineers will send out copies of the proposed decimal gauge, this committee asks to be continued to enable them to take it up promptly when received.

Very respectfully submitted,

E. D. MEIER, Chairman.
J. H. KINEALY,
W. H. BRYAN, Committee.

On motion of Mr. Crosby, seconded by Mr. Perkins, the resolution proposed by the committee was adopted and the committee continued.

On motion the secretary was directed to cast the ballot of the club for Mr. W. A. Layman, as librarian, which was done.

Prof. W. S. Chaplin, chancellor Washington University, then addressed the club on the subject of German engineering schools and engineering education in general. He visited Germany in the summer of 1894 and took occasion to make a special study of the technical high schools in Berlin and Hanover. He was first struck with the size and magnificence of the buildings, the idea being that expenditures of this character would impress the people favorably, and tend to make the schools rank favorably in comparison with the older universities. The schools were provided with elaborate collections of models, representing all sorts of machinery. These models, however, were not used by the students, but by the professors only. Chemistry was taught to enginering students by lectures only. No students, except those intending to be chemists, were allowed to handle chemicals. The theses were accompanied by very fine drawings, but it seemed that all the designs and computations were made by the professors, the student simply executing the drawings under the immediate direction of the professors. It was nec-

essary to pass two important examinations, one at the end of two years and the other at the end of four years, at which time the student graduated, and took the State examination. It was necessary to pass the latter if the student expected to follow the profession and find employment.

The professors in the technical high schools were looked down upon by those in the universities. Engineers were considered technical and not scientific men. In a recent discussion among German engineers regarding engineering education, it was considered that a ground work in theory was absolutely essential, but it was necessary also that the student be taught the application of the theories to every day problems.

German engineering students put in from forty-one to forty-four hours per week at school, while thirty-five hours is considered large in this country. Besides this, it is necessary to do a considerable amount of home work at night.

The Professor had expected to learn many things of value, but was disappointed. He thought that, on the whole, the training given by American engineering schools was much better suited to American conditions. The technical high schools are entirely distinct from the universities. There are no graduate students. Instruction is simply by lectures, text books being used only in mathematics. The standard of entrance is higher than in our schools, and the course of study more thorough, but the field covered is not as wide or as general. The schools are supported almost wholly by government grants, the fees paid forming probably not to exceed 10 per cent. of the income.

The discussion was participated in by Messrs. Holman, P. N. Moore, Sterne, Johnson, Hermann, Laird, Kinealy, Crosby and Bryan.

Adjourned.

WILLIAM H. BRYAN, Secretary.

Montana Society of Civil Engineers.

HELENA, Mont., March 9, 1895.—The regular monthly meeting of the Montana Society of Civil Engineers was held on Saturday evening, March 9, at the society's rooms in the Denver block. The meeting was called to order by President Keerl, the following members being present: Messrs. James S. Keerl, William A. Haven, H. C. Relf, A. E. Cumming, A. S. Hovey and Forrest J. Smith. Several visiting engineers and F. H. Ray were also present.

The applications of William Monroe, David A. Herron and James M. Calderwood, for membership in the society were read and approved, and the secretary was directed to send out a letter ballot to the members to be canvassed at the next regular meeting. The secretary then read a memorial prepared by a committee of the society, of Col. Walter W. de Lacy, late president of the society, a pioneer., soldier and prominent civil engineer, who was known and loved from the Mississippi to the Pacific, and from the British possessions to the city of Mexico. The memorial entered into the details of the colonel's life, from the date of his birth in Virginia to the time of his death in Helena about three years ago. It was a most interesting paper, giving a short sketch of the many adventures of this most remarkable man among the savages of the unexplored west of early days, as well as his achievements in the engineering profession.

Mr. Ray, who has been most untiring in his efforts to secure the passage of the country surveyor and road law bills by the legislature, then reported

that while he was unable to secure the passage of those bills as originally drafted by the society, he did succeed in the passage of House Bill No. 356 and a substitute for House Bill No. 124; that hile these bills left much to be desired, they were a step in the direction of securing good roads without additional expense, and that by carrying on a "campaign of education" we would in a few years be able to obtain the proper legislation to put the location and construction of our highways in the hands of men trained to the work.

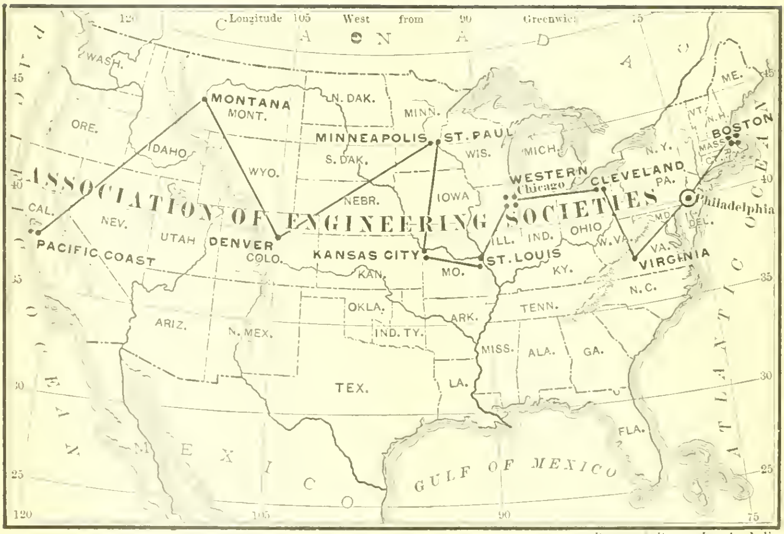
A vote of thanks was given Mr. Ray for his work done in the interest of "good roads," and he was invited to attend the meetings of the society. The secretary was also directed to communicate with Senators Folsom, Steele and Babcock; Representatives Shropshire, Tallant, Isdell, Metcalf, Gordon and Craven, and Messrs. Beach, Muth and Wheaton, commissioners of Lewis and Clarke county, and express the thanks of the society to them for the interest they took in the reform of our county surveyor and road laws, and for the aid they gave to the movement.

J. H. Farmer was present, with a paper on "Steam Power in Relation to Our Mills and Manufactures, Compared with Water Power by Electrical Transmission," but, as it was quite late, it was decided to defer the reading of this paper until the next meeting, when it is hoped that there will be a larger attendance, as the paper deals largely with the proposed Missouri River dam near Stubbs ferry and the transmission by electricity of power to this city.

A letter was read from Surveyor General Straughan, of Idaho, quoting the recent rulings of the Secretary of the Interior, in which he holds that a deputy United States mineral surveyor, residing in one State, may hold a deputy's commission and make mineral surveys in another State, thus reversing the ruling of the commissioner of the general land office.

The meeting then adjourned.

F. J. SMITH, Secretary.



Bradley & Poates, Engr's, N.Y.

Association of Engineering Societies.

Vol. XIV. APRIL, 1895. No. 4.

PROCEEDINGS.

Montana Society of Civil Engineers.

HELENA, Mont., April 13, 1895.—The regular monthly meeting of the Montana Society of Civil Engineers was held on Saturday evening, April 13, at the society's rooms, in the Denver Block. The meeting was called to order by President Keerl, the following members being present: Messrs. James S. Keerl, William A. Haven, H. C. Relf, Harry V. Wheeler and Forrest J. Smith. Mr. H. L. Cooper, of Minneapolis, member of the Western Society of Civil Engineers, and Mr. J. H. Farmer were also present.

Messrs. Haven and Wheeler were appointed tellers to canvass the ballots for admission to membership, and upon the completion of the count the president announced that Charles A. Molson, James M. Calderwood, David A. Herron and William Munroe had been elected members of the society.

A letter bearing date of March 14, from Walter H. Weed, of the Geological Survey at Washington, D. C., asking the society's opinion as to the most important area in Montana in which to prosecute this season's work was then read. The secretary stated that owing to the fact that immediate action had been necessary, and as the matter was of prime importance to the mining engineers of the State, he had referred the matter to the members of the society residing in Butte. They had met and discussed the subject and were of the opinion that the area demanding immediate attention is the degree square included between the 113th and 114th meridians, and the 46th and 47th parallels of latitude, which covers the mines of Granite, Philipsburg, Georgetown, Cable, Combination, Sunrise, Yreka, Royal Beartown, etc. The secretary also said that the Helena engineers were of the opinion that the most important area is that section which covers the mines of Basin, Lump Gulch, Red Mountain, Marysville, Jay Gould, Elkhorn, Radersburg, St. Louis, etc., and that he had written Mr. Weed, laying before him the two different opinions of the members, and that no doubt one of the two sections would be selected in which to carry on the government geological work this season.

Letters were read from Senator Babcock and Representatives Shropshire and Craven, expressing their appreciation of the society's efforts to

obtain legislation favorable to the improvement of our public highways, and also expressing the belief that in the near future legislators would realize the great importance of this subject and grant proper legislation.

Mr. J. H. Farmer then read a paper on "Steam Power in Relation to Our Mills and Manufactures, Compared with Water Power by Electrical Transmission." The paper was most interesting and gave evidence of thorough research and careful study on the part of the author, who is undoubtedly thoroughly familiar with the subject. It entered into the details of construction and cost of building a dam across the Missouri River, near Stubbs' Ferry, and transmitting the power by electricity to this city. It also developed the facts that the cheapest results obtained by recent tests, made by two of the largest plants in the State, of the cost per horse power per year generated by steam, was $71.50; while Mr. Farmer estimates that power can be transmitted from the dam to this city at $16.78 per horse power per year. A careful estimate shows that Helena now uses about 2000 horse power, and, in view of the fact that this would be more than doubled in a short time by the use of the cheap power mentioned above, it seems strange that capitalists should hesitate with a project which promises such large returns. A vote of thanks was given Mr. Farmer for his valuable paper, and the meeting adjourned.

FORREST J. SMITH, Secretary.

Civil Engineers' Society of St. Paul.

ST. PAUL, April 1, 1895.

A regular meeting of the Civil Engineers' Society of St. Paul was held at 8.30 P. M., thirteen members and twelve visitors were present. In the absence of the presiding officer Mr. A. O. Powell was called to the chair. Following the reading of the minutes of the previous meeting, Mr. C. A. Winslow was elected a member of the society.

Mr. George L. Wilson then read a brief historical sketch of the Chicago Drainage Canal, and illustrated, by lantern views, the method of excavating on several sections of the work. The pictorial display elicited many questions, which were satisfactorily met, and Mr. Wilson was quite generally given to understand that his work was thoroughly appreciated. Vice-President Hilgard appeared in time to close the meeting.

C. L. ANNAN, Secretary.

Engineers' Club of St. Louis.

415th Meeting. - April 3, 1895.

The club was called to order at 1600 Lucas Place, at 8.30 P. M., President Russell in the chair; fifteen members and six visitors present.

The minutes of the 414th meeting were read and approved. The Executive Committee reported the doings of its 186th meeting, approving the applications for membership of Joseph Ramsey, Jr. and George B. Leighton. They were balloted for and elected. An application for membership was announced from Thomas Ashburner, St. Louis agent of the Babcock & Wilcox Company.

Professor J. H. Kinealy then addressed the club on the "Different Methods of Determining the Heat Value of Fuels." Three plans are in common use: The Analytical, Bertier and Calorimetric. In the first

method the calorific power is computed from the chemical constituents of the fuel, they having first been determined by analysis. This process was open to the criticism that the heat value of pure carbon had been shown to vary as much as 3 per cent., depending upon the condition of the carbon. This computation also neglected the sulphur. On the whole, however, he considered this plan the best of the three.

In the second or Bertier method, the coal was burned in the presence of litharge, the heat value being assumed to be proportioned to the amount of oxygen absorbed from the litharge. This principle has been shown, however, to be erroneous, but the method nevertheless gives good comparative results.

The apparatus used in the third method is usually the Thompson calorimeter, in which the coal is burned in such a way as to give up its heat to a surrounding body of water of known weight, the rise in temperature of which is noted. This method was shown to have a considerable error depending upon the temperature of the water used and the heat absorbed by the apparatus itself. Its accuracy depends upon very close reading of thermometers. This method assumed that complete combustion of the coal occurred, which the speaker doubted. This possibility he proposed to investigate further by analyzing the discharge gases.

Messrs. Johnson, Fish, Moore and Bryan took part in the discussion.

Adjourned.

WILLIAM H. BRYAN, Secretary.

416th Meeting. April 17, 1895.

The Club was called to order at 8.15 P. M., by President Russell, at 1600 Lucas Place. Eighteen members and six visitors present.

The minutes of the 415th meeting were read and approved. The Executive Committee reported the doings of its 187th meeting, approving the application for membership of Mr. Thomas Ashburner. He was balloted for and elected. An application for membership was announced from Mr. H. A. Wagner, general superintendent of the Missouri Electric Light and Power Company and Edison Illuminating Company.

The secretary announced the receipt of a number of valuable publications for the library.

Professor Johnson then introduced Professor Leonard S. Smith, of the University of Wisconsin, Madison, Wis., who read a paper on "An Experimental Study of Field Methods which will Insure Greatly Increased Accuracy to Stadia Measurements."

The Professor had had occasion to make an exhaustive study of stadia methods and the effect of work done at various hours of the day, and under varying conditions of the atmosphere. Two points were covered: First, a study of what is known as boiling or unsteadiness of the air, the effect of which he termed differential refraction; second, the effect of this refraction upon the accuracy of stadia measurements.

The Professor had spent considerable time on this work in connection with the international boundary survey between this country and Mexico, and his experiments were continued last summer at Madison, Wis. His researches, which were very exhaustive, and made with the greatest care, enabled him to formulate some general suggestions regarding stadia work, which, if followed, would enable that system to be employed satisfactorily on work requiring a greater degree of accuracy than has heretofore been deemed possible.

In the discussion which followed, participated in by Messrs. Holman,

Kinealy, Johnson, Ockerson, Colby and Van Ornum, the universal opinion was that Professor Smith's work was of great value to the profession, as it marked a decided advancement in our knowledge of stadia work.

On motion it was ordered that the Club extend a vote of thanks to Professor Smith for his paper.

Adjourned.

WILLIAM H. BRYAN, Secretary.

Civil Engineers' Club of Cleveland.

CLEVELAND, O., April 9, 1895.

The meeting was called to order by President Mordecai at 7.45 o'clock. There were present thirty-seven members and visitors. Minutes of the last meeting, on March 12, were read and approved.

The application of Mr. Stephen Balkwill for admission to the Club as associate member was announced as approved by the Executive Board, and the following committees as appointed by the President:

Program Committee, Prof. C. H. Benjamin, chairman; Messrs. John Richardson, E. S. W. Moore, H. Grey, W. Rice, C. S. Howe and E. A. Handy. Finance Committee, Messrs. C. W. Wason, J. C. Wallace and W. Miller. Library Committee, Messrs. James Ritchie, J. L. Culley and F. A. Coburn.

A letter was read from the Electric Club extending thanks for the souvenir engraving. Letters were read from Professor J. B. Johnson, chairman of the Board of Managers of the Association of Engineering Societies, and Mr. John C. Trautwine, Jr., secretary, expressing their appreciation of our vote of thanks, and also from the secretary, making suggestions regarding advertisements in the journal.

Professor Benjamin, chairman of the Program Committee, reported progress in arranging the program for the coming year.

It was moved by Mr. William H. Searles and carried, that a committee of three on advertising be appointed by the President.

It was moved by Mr. Walter Miller and carried, that a committee of three upon new quarters be appointed by the President.

Professor Charles S. Howe then presented his paper: "Solar Attachments to Transits," and, in the absence of Mr. John B. Davis, Professor Howe continued, describing that gentleman's invention of a "New Solar Instrument."

Discussion of the subject was engaged in by Messrs. W. T. Blunt, William H. Searles, C. G. Force, J. D. Varney and B. F. Morse.

The President announced, as Committee on Advertising, Messrs. W. H. Searles, James Ritchie and C. M. Barber. As Committee on New Quarters, Messrs. W. Miller, A. H. Porter and J. C. Beardsley.

The meeting adjourned at 9.15 o'clock.

F. A. COBURN, Secretary.

Technical Society of the Pacific Coast.

April 5, 1895. Regular meeting. Called to order at 8.30 P. M. by President Dickie.

The minutes of the last regular meeting were read and approved.

The following candidates were declared duly elected to membership in the society after a count of the ballots:

MEMBERS.

Marion L. Cook, of Riverside, Cal.

Ernest F. Rossow, of Vallejo, Cal.

Albert I. Frye, of San Francisco, Cal.

The following names were proposed and referred to the Executive Committee:

FOR MEMBERS.

Walter E. Downs, Civil Engineer, of Sutter Creek, Cal. Proposed by Frank Soule, H. E. Clermont Feusier and Otto von Geldern.

Jno. B. Leonard, Draughtsman, of San Francisco. Proposed by J. H. Wallace, G. W. Dickie and John D. Isaacs.

Franklin Riffle, Civil Engineer, of San Francisco. Proposed by D. C. Henny, Thos. W. Brooks and H. C. Behr.

Mr. John D. Isaacs, of the Southern Pacific Company, read a paper entitled "Stopping a Troublesome Slide at a Summit Tunnel," which gave rise to an interesting discussion in which many of the members participated.

Adjourned.

OTTO VON GELDERN, Secretary.

The Secretary announces the death, on April 21, 1895, of Mr. George Beardsley, of Phœnix, Arizona, member of the Society.

Association of Engineers of Virginia, Roanoke, Va.

March 28, 1895.—The regular informal monthly meeting of the Association was held on March 28th, being postponed from March 20, on account of the very inclement weather. The meeting was called to order by the president, Mr. J. C. Rawn. An invitation to the Association from the Engineers' Club of the Va. A. and M. College to attend the lectures of Professor J. H. Gore, of Columbian University, on Geodecy, to be delivered April 5th and 6th, was read, and the secretary instructed to express the thanks of the Association. A communication from the librarian of the Ohio State University was read, asking for the publications of the Association of Engineers of Virginia. The secretary was instructed to send what had already been published and to state that hereafter all the papers of the Association would be published in the "Journal of the Association of Engineering Societies."

A communication from the Engineers' Club of St. Louis was read asking that this Association use its influence in bringing into general use the "Decimal Gauge" for wire and sheet metal that is to be proposed by the American Society of Mechanical Engineers and the American Railway Master Mechanics' Association.

A committee, consisting of Messrs. G. R. Henderson, C. S. Churchill and R. H. Soule, was appointed to draw up resolutions expressing the views of the Association in this matter and report.

The paper for the evening, "Cement from Furnace Slag," was called, and a very complete and interesting discussion of the subject was given by Mr. Herman Crueger. The chemical analysis of the various kinds of cement was given and along with it the analysis of the various furnace slags to be had in this section, showing clearly that it would be an easy matter to produce good cement at very low cost. The plan for a factory for its production, with estimates of cost, etc., were also given, making it a very interesting and instructive meeting. Paper referred to Publication Committee. Meeting adjourned.

JNO. A. PILCHER, Secretary.

* Manuscript received May 4, 1895. Secretary Ass'n of Eng. Soc.

April 17, 1895.—The regular informal monthly meeting of the Association was called to order, with President J. C. Rawn in the chair and a good number of the members present.

Professor L. S. Randolph, of Blacksburg, Va., read a very interesting paper on "Engineering Education," in which he brought out the distinctive features in the methods of teaching in England, in Germany and in America. The weak and the strong points of the different systems were brought out and discussed and the very important question of just how far the student in one branch of the profession should be carried into the others was raised. Also the question of how much time should be given to the practical and how much to the theoretical part of the training.

The discussion was entered into by a good number of those present and views on the subject were expressed by those who had seen or been under the different plans of instruction. The varied opinions and experiences of those who had seen the service were interesting and instructive.

The paper was referred to the Publication Committee.

Very truly,

Roanoke, Va. JNO. A. PILCHER, Secretary.

Boston Society of Civil Engineers.

APRIL 17, 1895—A regular meeting of the Society was held at its rooms, 36 Bromfield street, Boston, at 7.50 o'clock P. M. Sixty-five members and visitors were present.

President Albert F. Noyes, on assuming the chair, thanked the members for the honor conferred upon him in his election to the presidency for the coming year. He promised the society his best efforts to advance its work and solicited the earnest co-operation of each and every member.

The Secretary reported for the Board of Government that it had appointed the following special committees:

On Excursions—H. B. Wood, H. S. French, W. B. Fuller, J. W. Rollins, Jr., and I. N. Hollis.

On the Library—F. L. Locke, S. E. Tinkham, H. D. Woods, F. E. Sherry and M. S. Pope.

On Quarters—Thomas Doane, Desmond FitzGerald, E. W. Howe, M. M. Tidd and C. F. Allen.

Members of the Board of Managers—S. E. Tinkham, J. R. Freeman, Henry Manley and Fred. Brooks.

The report was accepted.

The Committee on Weights and Measures, which had been given until this meeting in which to submit its annual report, not having presented a report, on motion it was voted to refer to the Board of Government, with full powers, the continuance of the committee and the appointment of the members thereof.

The Secretary read a communication from the Board of Directors of the American Society of Civil Engineers, inviting this society to attend the annual convention to be held at the Hotel Pemberton, beginning June 18, 1895, and suggesting that it would be pleased to have the Boston Society co-operate in any way with the local committee of arrangements. The invitation was accepted, with the thanks of the Society, by a unanimous vote.

It was further voted, that a committee of three, to represent the Boston Society of Civil Engineers, be appointed by the President to aid the local committee of the American Society Civil Engineers in its work. Later in the meeting, the President named as the members of the committee, Messrs. Dexter Brackett, Fred. Brooks and T. Howard Barnes.

A communication was read from the Engineers' Club, of St. Louis, calling attention to the action of that club on the question of standard gauges for thickness of metals, and requesting this society to concur in the proposed action. It was voted to refer the communication to the Board of Government, to be reported upon in connection with the communication on the same subject from the American Society of Mechanical Engineers, now before the Board.

On motion of Mr. Wood, the thanks of the Society were voted to Major J. W. Reilly, U. S. A., for courtesies shown our members on the occasion of the visit to the Watertown Arsenal this afternoon.

The president announced the deaths of two members of the Society, John H. Webster, who died on April 2, 1895, and Adelbert L. Sprague, who died April 12, 1895. On motion the President was requested to appoint committees to prepare memoirs, and the following appointments were made: On memoir of Mr. Webster, Messrs. J. A. Tilden and J. R. Freeman; on memoir of Mr. Sprague, Messrs. F. O. Whitney and F. A. Foster.

Mr. Walton I. Aims, C. E., of New York, was then introduced, and read a paper entitled "Notes on the Construction of the East River Gas Tunnel."

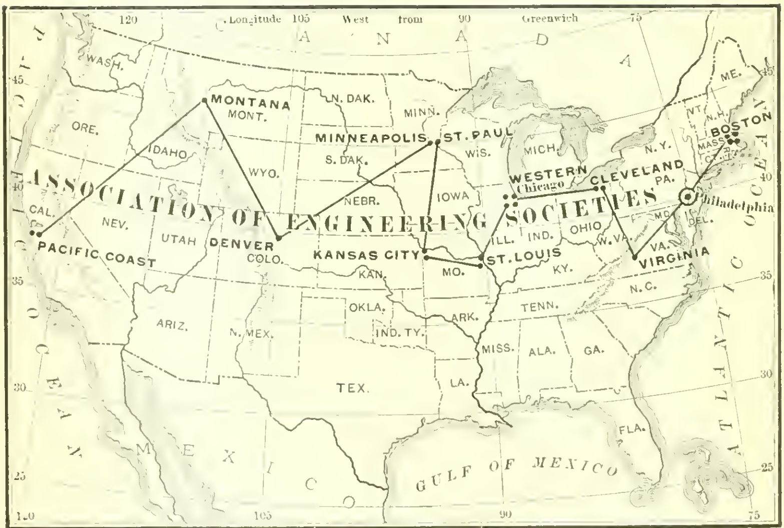
The paper gave a very full history of the work, and was illustrated by a large number of lantern views showing the details of the work.

At the close of the discussion which followed the reading of the paper, on motion of Mr. FitzGerald, the thanks of the Society were extended to Mr. Aims for his very interesting and valuabl paper.

On motion of Mr. Stearns it was voted to hold the June meeting of the Society on the 12th of that month.

Adjourned.

S. E. TINKHAM,
Secretary.



Bradley & Poates, Engr's, N.Y.

ASSOCIATION

OF

ENGINEERING SOCIETIES.

VOL. XIV. MAY, 1895. NO. 5.

PROCEEDINGS.

Engineers' Club of Minneapolis.

NOVEMBER 19, 1894.—Regular meeting called to order at 8 P.M., by the President, F. W. Cappelen, who announced the death of Charles F. Chapman, one of the early members of the Club.

William A. Pike stated that, as Secretary at the time, he could vouch for his having been an active member during his active connection with the Club, and moved that a committee be appointed by the Chair to draw up suitable resolutions. Carried. The Chair appointed as such committee, W. A. Pike, F. C. Deterly, I. E. Howe, and M. W. Hoffman.

Letter was read from O. Chanute, C.E., transmitting souvenir and medal from French Society, as a recognition of the treatment their delegates to the World's Columbian Exposition had received.

W. A. Pike reported as member of Board of Managers of JOURNAL of Associated Engineering Societies, that there was a deficit, and several plans for overcoming the same, and asked instructions.

W. A. Hoag moved to leave the matter in W. A. Pike's hands, and that the Club will sustain his action, also that the opinion of the Club was that the best plan was to make the necessary assessment to cover deficit. Carried.

The Committee then reported the following:

Whereas it has come to the knowledge of this meeting that Charles F. Chapman has been called away. Therefore we

Resolve, That in his death we have lost a most able and trustworthy engineer and friend, and we, as engineers, desire to express to his family our sincere regret for his loss, and our deepest sympathy with them.

On motion the report and resolutions were unanimously adopted, and the Secretary instructed to transmit a copy to the family.

On motion of I. E. Howe, F. C. Deterly, I. E. Howe and M. W. Hoffman were appointed a committee to represent this meeting at the funeral, and were empowered to procure flowers.

W. R. Hoag then read a paper on the State Topographical Survey of Minnesota.

E. E. Woodman, H. C. Stevens, and K. E. Hilgard, of the St. Paul Society, were present.

Moved that a committee be appointed to investigate the continuation of the State Topographical Survey, consisting of F. W. Cappelen, as Chairman, E. T. Abbott, and W. A. Pike. Carried.

E. E. Woodman, of the St. Paul Society, stated that their Society would at their next meeting appoint a committee to act with our committee.

On motion adjourned.

ELBERT NEXSEN, *Secretary.*

DECEMBER 17, 1894.—Regular meeting held at the Public Library, at 8 P.M., President F. W. Cappelen in the chair. Minutes of Meetings of March 19th, April 16th, May 21st, June 18th, July 16th, August 20th, September 7th, and November 19th, and also record of trip of Club and St. Paul Engineering Society, October 20th to 23d to Sault Ste. Marie, were read and approved.

Secretary read letter from Mrs. Charles F. Chapman thanking the Club for the resolution and flowers sent at the time of her husband's death.

F. W. Cappelen, Wm. A. Pike and E. T. Abbott, the committee appointed at the last meeting to consider the subject of the Topographical Survey of Minnesota, reported.

I. E. Howe moved the report be adopted. Carried.

Moved that a copy of the report, and the fact of its adoption by the Club, be sent by the Secretary to Hon. John S. Pillsbury, President of the Board of Regents of the University of Minnesota, to our United States Senators, W. D. Washburn, and C. K. Davis, and to our United States Representatives in Congress, J. A. Towney, J. T. McCleary, O. M. Hall, A. R. Kiefer, Losen Fletcher, M. R. Baldwin, H. E. Boen, and the Press of Minneapolis, and that the Secretary notify E. E. Woodman, of the Civil Engineers' Society of St. Paul, of the action taken. Carried.

On motion adjourned.

ELBERT NEXSEN, *Secretary.*

JANUARY 21, 1895.—The annual meeting was adjourned to February 4, 1895, as the Secretary and Treasurer had been suddenly called away from the city.

FEBRUARY 4, 1895.—Adjourned annual meeting held at the Public Library, at 8 o'clock, the President, F. W. Cappelen, in the chair.

The report of the Treasurer, showing receipts of $115.00 during the past year, and expenditures of $119.27, and a balance of $30.27 on hand to meet liabilities of $90.50, with assets due from members of Club, mostly good but slow, of $75.50, and recommending that the assessment for 1895 be made $5.00 for each member, payable at once, was read, and Carl Ilstrup appointed auditor to audit the accounts.

The Secretary's report was a statement of what the Club had done and is fully shown in the minutes.

These reports were accepted and ordered placed on file.

A motion making the assessment for current expenses for 1895, five dollars ($5) per member, payable at once, was carried unanimously.

The election of officers was postponed to a future meeting.

Mr. Harry W. Jones then read a paper embodying his views upon what an architect should be, and this was discussed by Mr. W. A. Pike, F. W. Cappelen, and A. B. Coe.

W. A. Pike offered the Club the use of his office, rent free, No. 822 Guaranty

Loan Building, as a place of meeting, and on motion the offer was accepted with the thanks of the Club.

The thanks of the Club were extended to Mr. Harry W. Jones for his very interesting paper, and a copy of the same requested.

On motion adjourned. ELBERT NEXSEN, *Secretary.*

MARCH 18, 1895.—A regular meeting was held at 822 Guaranty Loan Building at 8 o'clock P.M., and Wm. A. Pike was chosen chairman.

Minutes of previous meetings read and approved.

Communications as follows were read: Invitations from Civil Engineers' Club of Cleveland to F. W. Cappelen, as President, to be their guest at their Fifteenth Annual Banquet on March 20th; from the Boston Society of Civil Engineers extending a like invitation to their Thirteenth Annual Dinner on March 12th to our Secretary.

From the Secretary of the Civil Engineers' Society of St. Paul, transmitting a copy of resolutions, correcting a statement made in a Preamble to resolutions adopted by them February, 1895, on the subject of the United States Surveys, and as explanatory of this communication, the correspondence between the Presidents of the St. Paul Society and our Club.

On motion of Mr. Howe the Secretary was directed to express to the St. Paul Society the fact that the resolutions as transmitted were satisfactory as placing the facts relative to the drafting and adoption of the resolutions mentioned, relative to the United States Surveys, as jointly agreed upon by the committees of each Society.

The final report of the Committee on Efflorescence of Brick was then read by the Secretary, and discussed by Carl Ilstrup, I. E. Howe, and the Chair, all taking exception to some of the conclusions reached by the Committee, because the specimens as mounted were placed flat when exposed, with backing brick below and face brick above, instead of vertically, as the brick would be built in a wall—all considering this arrangement faulty. On motion the report was accepted, and ordered placed on file, and the committee discharged.

W. S. Pardee's bill for a balance of $11.80 for labor, material, etc., incurred by the Committee on Efflorescence of Brick, was presented and on motion of W. W. Redfield, the Secretary was directed to credit the same on account of W. S. Pardee's dues to the Club.

The chairman then announced the next business as the election of officers for 1895.

I. E. Howe moved that the election be postponed after a general discussion in which the unanimous sentiment was that it had been postponed too long already. The motion was lost.

E. H. Loe moved that the Secretary be instructed to cast the ballot of the Club for F. W. Cappelen for President. Carried unanimously.

The same motion by Carl Ilstrup, carried unanimously for I. E. Howe for Vice-President. These ballots having been cast by the Secretary and announced by the Chair, a motion that the Vice-President-elect cast the ballot of the Club for Elbert Nexsen for Secretary and Treasurer, and A. B. Coe for Librarian, and Wm. A. Pike for Member of the Board of Managers of the Association of Engineering Societies, was unanimously adopted, and so cast by him, and they were declared duly elected by the Chair to the several offices.

The name of Pedar Erlandsen was proposed for membership by Carl Ilstrup, and I. E. Howe.

On motion adjourned. ELBERT NEXSEN, *Secretary.*

Engineers' Club of St. Louis.

417TH MEETING, MAY 1, 1895.—President Russell called the Club to order at 1600 Lucas Place, at 8.25 P.M. Eighteen members and three visitors present. The minutes of the 416th meeting were read and approved. The Executive Committee reported the doings of its 188th meeting, announcing the approval of the application for membership of Mr. H. A. Wagner, general superintendent of the Missouri Electric Light and Power Company and Edison Illuminating Company. He was balloted for and elected. An application for membership was announced from Mr. Fred Schwedtmann.

The Secretary read a circular letter from the Western Society of Engineers on the subject of keeping the cost of the JOURNAL down to $3 00 per annum per member. After discussion by Messrs. Moore, Crosby, Kinealy, Winslow, Wheeler, Ockerson, Thacher and Bryan, Mr. Moore offered a resolution to the effect that it was the sense of this Club that the cost of the JOURNAL be limited to $3.00 per year per member, and that, if necessary to keep the cost within this limit, the "Proceedings" be omitted. This motion was seconded by Mr. Crosby and adopted.

Mr. William H. Bryan then addressed the Club informally on the subject of "Boiler Trials," the objects of which were usually the determining of the efficiency, capacity or smokelessness of the plant. He explained how such trials were made, the apparatus and instruments employed, and the results obtained, paying particular attention to the question of entrainment, or moisture present in the steam. He showed the Barrus and Carpenter Calorimeters for determining the quality of the steam, and explained their construction and use.

He gave the following figures as the result of a large number of investigations made on boilers and furnaces in and near St. Louis, burning soft coals:

Average efficiency of the common boiler and furnace, 51.35 per cent.; range, 44.8 to 60.4 per cent. Water tube boilers with common furnace, 60 to 70 per cent. Best form of improved furnace, under ordinary boilers, 58 to 69 per cent.; under water tube boilers, 70 to 75 per cent.

In capacity, the maximum evaporation in pounds water per square foot surface per hour from and at 212 degrees, was as follows:

For boilers with 2½-inch tubes	4.17
For boilers with 6-inch tubes	7.81
Flue boilers	8.86
Water tube boilers	7.26

The capacity on the basis of percentage of work done above the normal capacities of the boilers was as follows:

Boilers with 2½-inch tubes	81 per cent.
Boilers with 6-inch tubes	113 per cent.
Boilers with large flues	92 per cent.
Boilers with water tubes	70 per cent.

In smoke performance the average of five tests, made on common boilers and furnaces, was 44.7 per cent.—the range being from 11 per cent. to 75 per cent. The average of 18 determinations on improved furnaces was 7.8—the range being from .300 to 40 per cent. Deducting the latter abnormal figure, which was clearly due to inefficient handling, the average of the remaining 17 was 5.91.

Mr. Bryan then gave the results of some trials recently made on the boilers of the St. Louis & Suburban Railway. The boilers were of the ordinary horizontal type, with 6-inch flues. The first trial was made on boilers set with the Hawley furnace, the result in efficiency being 57.75 per cent., and the cost of evaporating 1,000 pounds of water, 12.2 cents, with Mount Olive lump coal, costing $1.50 per ton of 2,000 pounds.

The second test was made on similar boilers with the ordinary furnace, the result being 48.83 per cent., and 14.1 cents, respectively.

The third test was made on the same boilers burning slack coal costing $1.10, with results of 47.98 per cent., and 11.5 cents.

The fourth run was made with lump coal, with an automatic steam jet smoke abater attached, the result being 50.70 per cent. and 13.8 cents. Same results, corrected for steam used for jets, were 49.16 per cent. and 14.3 cents.

The steam used for the jets was supplied by an independent 8-horse power boiler, which was tested at the same time, giving results of 34.62 per cent. and 21.3 cents.

These figures indicate that no economy in fuel resulted from the use of the apparatus, but, on the other hand, it occasioned no loss. Some careful tests made by others indicate a fuel economy of from 5 to 10 per cent. under the best conditions, but Mr. Bryan was of the opinion that the ordinary non-automatic steam jets have usually increased the fuel bills.

Discussion followed by Messrs. Kinealy, Ockerson, Winslow, Laird and Wheeler.

Adjourned. WILLIAM H. BRYAN, *Secretary.*

418TH MEETING, MAY 15, 1895.—President Russell called the Club to order at 1600 Lucas Place at 8.20 P.M. Twenty members and ten visitors present.

The minutes of the 417th meeting were read and approved. The Executive Committee reported the doings of its 189th and 190th meetings.

The Secretary read an informal progress report of the Committee on Standard Gauges for Thickness, showing that the movement for a decimal system was receiving widespread consideration and approval. The Secretary also read a letter from the Chairman of the Board of Managers of the Associated Engineering Societies, stating that immediate steps would be taken to make such changes as were necessary to keep the cost of the JOURNAL within $3.00 per member per year.

Mr. M. A. Howe, Professor of Civil Engineering, Rose Polytechnic Institute, Terre Haute, Ind., then addressed the Club on the subject of "Recording Bridge Deflections." He described in detail a series of experiments made by himself and classes of students in 1892 and 1894, the primary object being the collection of data for the students' theses. Very complete measuring and recording apparatus had been devised to determine the effect of moving and stationary loads on pin connected bridges, in vertical, lateral and longitudinal deflections, these three being recorded independently.

The Professor was of the opinion that the vibrations were much less than had been heretofore assumed. In several cases he had computed the deflections from approved formulæ and had found the result considerably more than that actually observed. In the particular cases considered, he believed this due to the fact that the top and bottom chords were practically continuous girders, and therefore carried a large proportion of the strain.

The discussion was participated in by Messrs. Crosby, Johnson, Ockerson, Moore, Baier and Sterne.

It was stated that the counterbalancing of locomotive drivers had been very much overdone, and that the best practice nowadays was to reduce it materially.

On motion of Professor Johnson, a vote of thanks was tendered Professor Howe for presenting his paper in person.

Adjourned. WILLIAM H. BRYAN, *Secretary.*

Technical Society of the Pacific Coast.

REGULAR MEETING HELD MAY 3, 1895. Called to order by President Dickie. The minutes of the last regular meeting were read and approved. After regular ballot the following gentlemen were declared duly elected members of the Society: Walter E. Downs, Civil Engineer; John B. Leonard, Civil Engineer; Franklin Riffle, Civil Engineer.

Mr. John B. Leonard thereupon read a paper entitled "Reconstruction of the Ferry Transfer Aprons at Port Costa and Benicia," after which a full discussion of the subject was entered upon. Adjourned.

OTTO VON GELDERN, *Secretary.*

Civil Engineers' Society of St. Paul.

ST. PAUL, MINN., MAY 6, 1895.—A regular meeting of the Civil Engineers' Society of St. Paul was held at 8.15 P.M. Fifteen members and five visitors were in attendance, President Stevens presiding. Minutes of previous meeting were read and approved. A circular letter from the Board of Directors of the Western Society of Engineers, relating to the prospective cost of publication of the JOURNAL of the Association was referred to Representative Woodman with power to act. As a matter of suggestion votes were taken to determine the sense of the meeting on two points only, with the following result: (1) Should it become necessary to discontinue any one department of the JOURNAL, the "Proceedings" should be dropped. (2) The "Index to Current Literature" should remain a feature of the JOURNAL at all events.

The following report of the Committee on Standard Wire Gauges was read and accepted. Mr. J. D. Estabrook then read a description of the new steam plant at the Washburn Flour Mills in Minneapolis, and Mr. William A. Pike described a test of its main feature, the Schichau Engine.

The discussion was somewhat extended over foaming glass and sandwich at the Café Neuman.

C. L. ANNAN, *Secretary.*

ST. PAUL, MINN., May 6, 1895.

President of the Civil Engineers' Society, St. Paul, Minn.:

DEAR SIR.—The committee appointed to investigate standard gauges by request of the American Society of Mechanical Engineers begs leave to make the following report:

Your committee are unanimously of the opinion that the gauges now in use, of which there are about forty (40), are in a state of confusion, and one of the most

serious matters in connection with the present system is the uncertainty of ordering material to a standard gauge, and also the gauge number as now used conveys no idea as to the thickness of the plate or wire designated. We would, therefore, recommend the use of a standard gauge, using as a basis the one-thousandth of an inch.

We do not believe that the French system of measurement has made any material progress among the manufacturers and mechanics of the United States, and therefore do not believe it would be advisable to undertake to measure with the French system as a gauge basis.

Your committee, therefore, proposes the following resolutions:

Resolved, That the Civil Engineers' Society of St. Paul recommends to its members, and to manufacturers using a gauge system, to abandon the old arbitrary gauges now in use and give the actual thickness and diameters in thousandths of the inch.

Resolved, That the Secretary of the Club be instructed to send copy of this report to the Secretary of the American Society of Mechanical Engineers, indorsing their report in reference to gauges.

Respectfully,

OLIVER CROSBY, *Chairman.*
TRACY LYON.
A. H. HOGELAND.
MAX TOLTZ.
W. C. MERRYMAN.

AT a special meeting of the Civil Engineers' Society of St. Paul, held May 30, 1895, the following resolution was passed:

Whereas, the Civil Engineers' Society of St. Paul, after examining the maps and works of the United States Geological Survey, and approving of the methods and work heretofore done in this vicinity, is desirous that the same should be continued. Therefore,

Resolved, That as said work is of great economic value to the Twin Cities, we do hereby request Senator Davis to urge the continuation of the work in the territory contiguous to the Twin Cities and the publication of maps of the same.

C. L. ANNAN, *Secretary.*

Montana Society of Civil Engineers.

MAY 13, 1895.—The regular monthly meeting of the Montana Society of Civil Engineers was held at the Secretary's rooms in the Denver block on Broadway. President Keerl called the meeting to order, the following members being present: Messrs. Keerl, Haven, Bayliss, Henley, Kelley and Smith. The application of Frederick J. Taylor for membership to the society was read and approved and the Secretary was instructed to prepare a letter ballot and send it to the members, to be canvassed at the next regular meeting.

A committee consisting of A. E. Cumming and H. V. Wheeler was appointed to prepare new forms of "quartz locations" and "water rights" to conform to the new law passed by the last legislature. This committee will report at the meeting to be held June 8, and as the new law does not go into effect until July 1, it is the

hope of the society that the printers generally will adopt these new forms and thus secure uniformity throughout the State.

The Secretary read a letter from the Board of Directors of the Western Society of Engineers, of Chicago, in reference to the cost of publishing the JOURNAL OF THE ASSOCIATION OF ENGINEERING SOCIETIES. A committee consisting of W. A. Haven and C. W. Goodale was appointed to investigate the matter thoroughly and report at the next regular meeting.

FORREST J. SMITH, *Secretary.*

The Civil Engineers' Club of Cleveland.

MAY 14, 1895.—Notwithstanding a severe storm, members of the Club and visitors to the number of twenty met at Case Library in the afternoon, visited Case School of Applied Science and united with others in an inspection of that enterprising, modern college.

The complete facilities for study and investigation there shown and the thorough methods of teaching, were examined and appreciated.

The party, numbering thirty, took supper at the Forest City House, after which they adjourned to the rooms of the Club at Case Library.

The meeting was called to order at 7.45 P.M. by President Mordecai. There were present 93 members and visitors. The Club dispensed with the reading of the minutes. Messrs. Herman, Thompson and Constant were appointed tellers to canvass ballots.

Reports were given by the Executive Committee and the Committee on Advertising and the complete program for the meetings for the year, as prepared by the Program Committee, was read; after which the Club listened to the paper of the evening by Dr. Dayton C. Miller.

The object of the lecture was to explain polarized light in a simple and concise manner. The elementary phenomena of light were briefly treated. Polarized light, its production and detection, were described. The beautiful color phenomena, resulting from the action of thin plates of doubly refracting substances upon the polarized light, showing designs in complementary colors, and the ring system of crystals, were explained and exhibited. Brief mention was made of the application of polarized light in the arts. The lecture was beautifully illustrated by means of an arc light projection polariscope.

This interesting lecture and beautiful exhibition were enthusiastically received by the unusually large audience.

The tellers reported the election of Mr. Stephen Balkwill to associate membership, and at 10 P.M. the meeting adjourned.

A pleasant innovation at this evening's meeting was the presence of ladies, some of whom had attended the excursion of the afternoon and the supper afterward.

The gentlemen enjoyed their presence. May they be with us often.

FORREST A. COBURN, *Secretary.*

Boston Society of Civil Engineers.

MAY 15, 1895.—A regular meeting of the Society was held at its rooms, 36 Bromfield Street, Boston, at 7.45 o'clock, P.M., President Albert F. Noyes in the chair. Seventy-eight members and visitors present.

The record of the last meeting was read and approved.

Messrs. Arthur A. Fobes, Philip Marquand, Walter W. Patch, and Hartley L. White, were elected members of the Society.

The Secretary reported for the Board of Government that it had voted to continue the Committee on Weights and Measures with the following membership: Charles T. Main, Allen Hazen and Dwight Porter. The Board also recommended that the communications in relation to a standard of thickness for metals, from the American Society of Mechanical Engineers, and from the Engineers' Club of St. Louis, be referred to the Committee on Weights and Measures for its consideration and that the Committee be requested to report to the Society what action it deemed advisable. On motion the recommendation of the Board was adopted.

The Secretary read a circular letter from the Board of Direction of the Western Society of Engineers addressed to the several societies, members of the Association of Engineering Societies, relating to the cost of the JOURNAL. On motion it was voted to refer the letter to the members of the Board of Managers representing the Boston Society for answer.

The Secretary read a letter from the Committee of the American Society of Mechanical Engineers on Standard Thicknesses for Gauges, transmitting a blue print showing proposed decimal gauge. The communication was referred to the Committee on Weights and Measures.

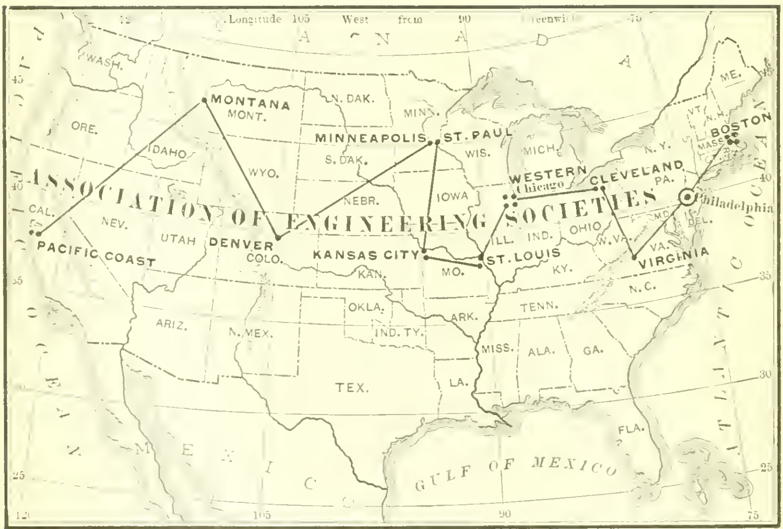
A letter was read from Mr. E. L. Corthell, a member of the Society, enclosing a report of the Mexican Association of Engineers and Architects, in relation to the formation of an International Institute of Engineers and Architects. The letter and report were referred to the Board of Government.

On motion of Mr. Brooks, it was voted to appropriate the sum of $225.06 for the payment of the special assessment for 1894, of the Association of Engineering Societies as per bill dated April 22, 1895.

Mr. J. Parker Snow then read a paper entitled "Wooden Bridge Construction on the Boston & Maine Railroad." The paper was discussed by Messrs Guppy and Rice.

Mr. R. S. Hale followed with a paper entitled "Approximate Analysis of the use of Coal in an Edison Electric Station of the Type Standard About 1890," which was discussed in a short paper by Mr. George H. Barrus, read by the Secretary. Adjourned.

S. E. TINKHAM, *Secretary*.



Bradley & Poates, Engr's N.Y.

Association of Engineering Societies.

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PROCEEDINGS.

The Civil Engineers' Club of Cleveland.

Case Library Building, Cleveland, Ohio, May 11, 1895.—The regular meeting of the Civil Engineers' Club, Tuesday evening, June 11, 1895, was called to order by President Mordecai. There were present thirty-two members and visitors. The minutes of the last meeting were read and approved. The application for admission as active member by Richard Hoffman, C.E., was read.

President Mordecai announced the death of a former member of the Society, Mr. A. M. Wellington. Mr. James Ritchie moved that a committee of three be appointed to draw up proper resolutions in regard to his death. Mr. Thompson spoke feelingly in regard to Mr. Wellington, and the motion was carried.

It was moved by Mr. Culley and carried that a committee of seven be appointed to arrange for a picnic.

The Club then listened to the paper of the evening by Mr. Frank Aborn, entitled, "Some Facts Concerning Drawing for Engineers."

Mr. Aborn spoke of drawing, as a natural language, a method of expression. He compared dimension and pictorial drawing ; showed the value of the latter, and the obstacles to its acquisition, and that skill is to be acquired by intelligently directed effort in freehand drawing.

It was a very interesting paper. The practical importance of this increasing and valuable means of communicating ideas, and the simple method of acquiring skill by freehand practice, were illustrated in a clear, practical manner.

Remarks were offered by Messrs. Benjamin, Herman, Culley, and others, after which the President appointed, as committee upon resolutions upon the death of Mr. Wellington, Messrs. Thompson, Ritchie and Searles.

As Committee on Picnic, Messrs. Gobielle, Culley, Warner, Jewett, Miller, Thompson and Beardsley.

The meeting adjourned.

F. A. Coburn, *Secretary.*

Engineers' Club of St. Louis.

419th Meeting, June 5, 1895.—The Club was called to order by President Russell at 8.25 p.m., at 1600 Lucas Place. Eighteen members and five visitors present.

The minutes of the 418th meeting were read and approved. The Executive Committee reported the doings of its 191st meeting, announcing that arrangements had been made for a meeting of the Club on June 19th, on which date Mr. H. A. Wheeler will present a paper on "Vitrified Brick for Street Paving."

Applications for membership were announced as follows: Clinton Kimball, assistant engineer, Bell Telephone Company, of Missouri; John J. Lichter, Jr., engineer Union Depot Railway Company; H. H. Sykes, chief engineer, Bell Telephone Company, of Missouri.

Mr. Bryan stated that a meeting of the local membership of the American Society of Mechanical Engineers had been held, the unanimous sentiment of which was, that arrangements be made to invite the Association to hold its Spring meeting of 1896 in St. Louis, and it was thought that the movement would be strengthened by being indorsed by the Engineers' Club of St. Louis. On motion of Mr. Moore, it was ordered that the Executive Committee extend, on behalf of the Engineers' Club of St. Louis, an invitation to the American Society of Mechanical Engineers, to hold their Spring meeting of 1896 in St. Louis.

President Russell stated that the settling basins at the Chain of Rocks would soon be cleaned, and invited the Club to visit the works. Mr. Holman extended a formal invitation to the Club to visit the works on the afternoon of Saturday, 15th inst. Mr. Crosby stated that he would make arrangements for the transportation of the Club. Ordered that the invitations be accepted, and that the Executive Committee complete the necessary arrangements.

Mr. Edward Flad then addressed the Club on the subject of standpipes, making special reference to a tower designed by him and just completed at St. Charles, Mo. Its dimensions were 25′ in diameter by 70′ high; capacity 250,000 gallons. It was encased in brickwork tied to the tower itself. The standpipe was stiffened by six circular girders, the object of which was to maintain the circular shape of the tower, so as to afford maximum strength to resist wind pressure. These girders were on the outside of the tank, occupying the space of 2′ between the tower itself, and the casing. A stairway was also placed in this space. The standpipe was covered by a roof of iron and slate. Due attention had been given to architectural features. The cost of the stand-pipe was: for iron work, $4,450; brick work, $2,807; foundation, $677, total $7,934. Mr. Flad also showed a tower designed by him for Laredo, Texas. He showed stereopticon views of the St. Charles, Laredo, and other towers of recent design, as well as a number of towers which had failed.

Messrs. Johnson, Holman, Baier, Bryan, Gayler, Moore, and Crosby, took part in the discussion. Adjourned.

William H. Bryan, *Secretary.*

420th Meeting, June 19, 1895.—The Club was called to order at 8.30 p.m., by Vice-President Ockerson, at 1600 Lucas Place, seventeen members and nine visitors present. The minutes of the 419th meeting were read and approved, as also a brief record of the excursion of 15th inst. The Executive Committee reported favorably on the applications for membership of Messrs. Clinton Kimball, J. J. Lichter, Jr., and H. H. Sykes. They were balloted for and elected.

On motion of Mr. Hermann, votes of thanks were unanimously tendered to Messrs. W. C. Brown and B. L. Crosby, of the Burlington System and to Water Commissioner Holman for courtesies extended in connection with the excursion to Chain of Rocks and Bellefontaine Bridge on 15th inst.

Mr. H. A. Wheeler then addressed the Club on the subject of "Vitrified Brick

for Street Paving." This material had been used in Holland for over a century, and in the North of England for a slightly shorter period. In Charleston, West Virginia, it had been in use for twenty-five years, and in Bloomington, Illinois, for twenty years, since which time its use has greatly increased, it now being employed in some four hundred cities and towns in this country. This year marks its adoption in the larger and more conservative cities of St. Louis, Chicago and New York. Mr. Wheeler gave a definition of the term "vitrified" brick, and explained the process of manufacture, the material used, and exhibited numerous samples. The clays employed were: the superficial, or common earth ; the shales; and the impure fire clays. The first is so difficult of treatment that its use is now rare. The shales furnish the best and most commonly used material. The fire clays, however, were frequently employed satisfactorily. A necessity of prime importance is slow cooling of the kilns. It is now quite possible to secure a paving brick of high grade, providing engineers will insist upon quality, and pay a price which will warrant greater care in every detail of manufacture, and more time in cooling. Laboratory tests are frequently misleading. Satisfactory inspection can be made at the yard by an experienced man simply by the eye and the hammer. Tests made in the laboratory covered the crushing, crossbreaking, absorption, and the tumbling of brick in a foundry rattler. Mr. Wheeler suggested that it would be well to add tests of density and hardness. The uses of these brick were for foundations, sewers and street paving, for which latter place the speaker believed them to possess important advantages over all other material, being harder than granite. The use of vitrified brick for streets and sewers would permit the cleaning of the streets by the hydraulic system.

The discussion was participated in by Messrs. Kinealy, Crosby, Chauvenet, Baier, Harrington and Ockersman. Adjourned.

WILLIAM H. BRYAN, *Secretary.*

Technical Society of the Pacific Coast.

REGULAR MEETING HELD JUNE 7, 1895. Called to order by Vice-President Curtis.

The minutes of the last regular meeting were read and approved.

After a ballot, Mr. Edward S. Cobb was elected to membership in the Society.

The Secretary read a letter, announcing the death of Mr. George Beardsley, a member, of Phœnix, Arizona.

The Chair appointed Messrs. C. E. Grunsky and D. C. Henny a committee to draw suitable resolutions in memory of the deceased member.

President George W. Dickie read a paper, entitled "Engineers; Consulting, Inspecting and Contracting; Their Relationship to each Other and to the Public," which was opened for discussion, and viewed from different standpoints by the members present. Adjourned.

OTTO VON GELDERN, *Secretary.*

Montana Society of Civil Engineers.

HELENA, MONT., JUNE 8, 1895.—The regular monthly meeting of the Montana Society of Civil Engineers was held on Saturday evening, June 8th, at the Society's rooms, in the Denver Block, on Broadway. President Keerl called the meeting to order, the following members being present: James S. Keerl, William

A. Haven, A. E. Cumming, A. S. Hovey, Walter S. Kelley and F. J. Smith. The minutes of the last regular meeting were read and approved.

The President then appointed Messrs. Haven and Cumming tellers to canvass the ballots for admission to membership, and upon completion of the count the President announced that Frederick J. Taylor had been unanimously elected a member of the Society.

The committee, consisting of Messrs. Haven and Goodale, appointed to investigate the cost of publishing the JOURNAL OF THE ASSOCIATION OF ENGINEERING SOCIETIES, then made an exhaustive report in writing, which gave evidence that the matter had been thoroughly investigated in all its details. The report had reference particularly to the circular letter of the Western Society of Engineers, and the committee stated that it found no basis for some of the statements in that letter relative to an "apparent excessive cost of the JOURNAL for 1895." The report was accepted as being the sense of the Society, and the Secretary was directed to send a copy of it to Prof. J. B. Johnson, chairman of the Board of Managers of the Association.

A. E. Cumming, chairman of the committee appointed to prepare blanks for quartz lode and placer location notices, to conform to the new law which goes into effect July 1st, reported that the committee had spent considerable time in looking up the law, etc. He called the attention of the members present to the various important requirements in the new law, and submitted to the meeting the blank forms of location notices as prepared by the committee. He also stated that he had submitted these blanks to a prominent attorney for inspection and that the attorney had pronounced them all right. A motion prevailed that the report be accepted, that the blanks as prepared by the committee be adopted and that the Secretary be instructed to have a sufficient number of these blanks printed to send to all the publishers in the mining districts of the State, and to each member of the Society. The Society hopes that these blanks will meet with the approval of the various publishers, and that these forms will be adopted, thus securing uniformity throughout the State.

A committee of one, consisting of James S. Keerl, was appointed to confer with the librarian of the public library as to the most desirable books on engineering to be purchased for the library.

A paper on the Cost of Steam and Water Power, Montana, prepared by Maurice S. Parker, of Great Falls, was then read by the Secretary. This paper was a most interesting one. It contained tables showing the cost per horse-power per day and per year, produced by steam and water. The remarkable cheapness of the cost of producing power by water, as compared with steam, left little room for doubt that in Montana, with her mountain torrents, steam will soon take second place. The paper throughout showed that the author was thoroughly familiar with his subject.

After discussion of the subject by all the members present the meeting adjourned.

FORREST J. SMITH, *Secretary.*

Boston Society of Civil Engineers.

JUNE 12, 1895.—A regular meeting of the Society was held at its rooms, 36 Bromfield Street, Boston, at 8.30 o'clock, P.M., President Albert F. Noyes in the chair. Number of members and visitors present, including ladies, eighty-six.

On motion it was voted to dispense with the reading of the record of the last meeting.

Messrs. George W. Fuller, Frank O. Melcher and Sanford E. Thompson were elected members of the Society.

The President and Treasurer were authorized to change the Society's rooms, provided the increased cost per year does not exceed one dollar per member.

The thanks of the Society were voted to the trustees of the Massachusetts General Hospital Association and to the officials of the New York, New Haven and Hartford Railroad Company, for courtesies shown members of the Society on the occasions of the excursions on May 15 and June 12, 1895.

Mr. F. O. Whitney, for the committee appointed to prepare a memoir of Adelbert L. Sprague, submitted its report, which was read and accepted.

Mr. Main, for the committee on weights and measures, presented the following resolution:

Resolved, That the Boston Society of Civil Engineers earnestly deprecate the use of any of the wire and sheet metal or other trade gauges now in vogue, and strongly urge the use of one-thousandths of an inch for all kinds and classes of small measurements. On motion it was voted to print the report of the committee in the notice of the September meeting and to defer action on the report until that meeting.

A paper by Francis C. Tucker was then presented, giving the engineering history of a lawsuit growing out of a contract for building a portion of the Grand Island & Wyoming Central Railroad, through the Black Hills of South Dakota. It was voted to print the paper in the JOURNAL with such discussions as may be offered

The rest of the evening was devoted to the exhibition of a series of beautiful lantern views presented by Mr. FitzGerald and President Noyes.

Adjourned. S. E. TINKHAM, *Secretary*.

Western Society of Engineers.

The 327th meeting was held in the Society's rooms on Wednesday, April 3, 1895, at 8 P.M. President Horton in the chair, and 62 members and guests present.

The minutes of the annual meeting were approved as printed in the JOURNAL OF THE ASSOCIATION OF ENGINEERING SOCIETIES.

The minutes of the March meeting were read and approved.

The Secretary reported for the Board of Directors—About ninety volumes of periodicals are being bound for the library.

The application of Mr. Charles F. White, of Chicago, for membership in the Society, was filed March 19, 1895.

The Secretary was instructed to have printed 1,000 copies of the Constitution, By-Laws and List of Members.

April 2, 1895, the following named gentlemen were elected to membership in the Society: As members—Messrs. George M. Basford, C. V. Brainard, William S. Dawley, Nicholas D. Pound, Leonard Sewall Smith, George E. Waldo, Charles F. White and Edward Dana Wickes. As associates—Messrs. George Horace Bryant and Charles F. Quincy. The application of William D. Pickels, as member, and William Edmund Syer, as junior, both of Chicago, were received and placed on file.

The death of Mr. Warren Collier Smith, a member of the Society, was announced, and on motion the President appointed Messrs. Isham Randolph, Frederic S. Brown and James J. Reynolds a committee to prepare a memorial of the deceased member.

A letter from Mr. E. L. Corthell, from Berne, Switzerland, in acknowledgment

of the cablegram sent him by the Society, at the annual banquet, was read by the Secretary.

Messrs. Frank C. Hatch, John Saltar, Jr., and H. F. J. Porter, were appointed a committee on "Standard Gauges for Thickness of Metals," in conformity with a request of the Engineers' Club of St. Louis.

Mr. R. H. Bethel was appointed on the Committee on Excursions and Entertainment, *vice* Mr. James J. Reynolds resigned.

The meeting was interspersed with vocal music and the "Club Smoker" with its concomitant features, all of which seemed to be very fully enjoyed. At a late hour the meeting adjourned.

At the meeting of the Board of Directors, held April 16, 1895, applications for membership in the Society were received and placed on file, as follows: As members—Louis K. Comstock and Howard Berge, both of Chicago. As Associate—Francis W. Lane, Chicago.

A special meeting (328th of the Society) was held in Science Hall, Armour Institute, Chicago, on Wednesday, April 17, 1895, at 8 P.M. Vice-President Morehouse in the chair and 82 members and guests present.

The Committee on Excursions and Entertainments, through its chairman, Mr. Appleton, outlined a very attractive list of proposed excursions, the next one to occur on April 27th.

Mr. Horace E. Horton read a paper, "The Highway Bridges Across the Mississippi River," illustrated by many lantern views, and accompanied by interesting notes of the various bridges, as the views were presented.

After discussion, the meeting adjourned.

CHARLES J. RONEY, *Secretary.*

The 329th meeting of the Society was held in the Society's rooms on Wednesday, May 1, 1895, at 8 P.M. Vice-President Morehouse in the chair, and about 35 members and guests present. The minutes of the February meeting were approved as printed in the JOURNAL OF THE ASSOCIATION OF ENGINEERING SOCIETIES. The minutes of the April meetings were approved as printed.

The Secretary reported for the Board of Directors—The following applications for membership were filed April 16, 1895. As Members—Louis K. Comstock and Howard Berge, both of Chicago. As Associate—Francis W. Lane, Chicago. On April 30th the following persons were elected: As Members—Howard Berge, Louis K. Comstock and William D. Pickels. As Junior—William Edmund Syer. As Associate—Francis W. Lane.

The application of Casper L. Redfield as Member and of Norwood De Hart as Junior were filed April 30, 1895.

Mr. Gerber, for the Committee on Excursions and Entertainments, announced arrangements for an inspection trip over the Metropolitan West Side Elevated R. R., and visit to the Power House, for Saturday, P.M., May 18, 1895.

Mr. Chanute, for the Committee on Library, asked for suggestions from members as to the best disposition to be made of a balance of the Library fund, amounting to about $75.

Mr. Chanute presented a resolution regarding a simultaneous reading and discussion by the various Societies in the Association of Engineering Societies of valuable papers originating in any of the Societies.

The resolution was referred to the Board of Directors for consideration and report to the Society at the regular meeting in June.

The following resolution, presented by Mr. James J. Reynolds, was unanimously adopted:

"*Resolved*, That this Society learns with regret the recent death of Gen. John Newton, in New York, and hereby places on record its sense of the loss thus sustained by the engineering profession and its high appreciation of his distinguished services."

By vote, the date for the next meeting at Armour Institute was changed from the third Wednesday in the month to the preceding Tuesday, 14th instant.

The question as to what grade or grades of members are entitled to wear the badge of the Society was referred to the Board of Directors for recommendations.

The 330th meeting of the Society was held in Science Hall, Armour Institute, at 8 P.M. Tuesday, May 14, 1895, President Horton in the chair; 36 members and guests present.

The paper of the evening, "The De Kalb, Ill., Municipal Electrical Pumping Plant," was read by the author, Mr. Daniel W. Mead, and was illustrated by lantern views. The reading of the paper was followed by an extended and animated discussion, and the meeting adjourned at a late hour.

On Saturday afternoon, May 18th, through the courtesy of the officials of the Metropolitan West Side Elevated R. R. Co., about 108 members and guests assembled at the Franklin Street terminus of this road and, after an inspection of the bridge over the South Branch, boarded a special train at 2.30 P.M. for a trip over the main line to West 48th Street, inspecting the Power House on the return trip.

CHARLES J. RONEY, *Secretary*.

The 331st meeting of the Society was held in the Society's rooms, 1737 Monadnock Block, Chicago, on Wednesday evening, June 5, 1895. President Horton in the chair; about fifty-five members and guests present.

The minutes of the meetings and report of the excursion of the previous month were read and approved.

The Secretary reported for the Board of Directors: At the meeting of the Board of Directors held June 4, 1895, Mr. Casper L. Redfield was elected a Member, and Mr. Norwood De Hart was elected a Junior.

The resolution offered by Mr. Chanute at the regular May meeting of the Society and referred to the Board, relating to simultaneous reading and discussion of papers in the participating societies of the Association, was considered, and it was voted that it was inexpedient to act on this resolution pending the report of the Board of Directors concerning the management of the JOURNAL, to be presented to the Society at the June meeting.

It was also voted that the blue badge of the Society should be worn by the grades of Members and Honorary Members only, and that Associates or Juniors may wear badges of the design, but in red enamel.

The action thus taken is presented as the recommendation of the Board in these matters.

Mr. Morehouse presented the following report of a Special Committee of the Board, which was accepted by the Board of Directors and is now presented to the Society.

The Secretary then read the communication which, in part, is as follows:

Your Board of Directors believe that the Association should be restricted in the unlimited powers at present conferred upon it, and, to that end, now makes to this Society the following recommendations as rules hereafter to be observed in the publication of the JOURNAL:

1. The object of the JOURNAL is to print the papers and transactions of the Societies, and it is not for the purpose of establishing a professional monthly magazine.

2. The amount of matter must be restricted to that which can be published at a cost of $3.00 per annum for each person on the mailing list of each Society, except as hereinafter provided.

3. The amount of matter which each Society is entitled to have published to be in direct proportion to the amount it contributes to the cost of publication.

4. Any Society desiring to publish matter in excess of its proportion, may publish such matter by paying the full extra cost thereof.

5. No Society having dues or assessments in arrears for more than 90 days after notice, or whose arrearages shall at any time exceed $2 per member, shall participate in the privileges of the Association; nor shall it be in the power of the Board of Managers to deviate from enforcing this rule.

6. A paper shall be accredited to the Society before which it is read, but the author, if a member of any Society or Societies of the Association shall be credited with such membership and none other.

7. The Association shall not have power to make any contracts or incur any liabilities which will bind the Association to an expenditure beyond the limitations specifically permitted by the Articles of Association.

8. The Secretary of the Association shall not have authority to edit any papers sent for publication, except by specific consent of the Society furnishing the paper.

9. Advertisements may be received by and inserted in the JOURNAL by its management, but all contracts therefor must terminate in the calendar year of the contract.

10. The Association shall not publish in the JOURNAL any other matter than the papers and transactions of the Societies, if it shall appear that by so doing the cost will exceed $3.00 per annum per member of the Societies.

11. The Association may secure subscriptions to the JOURNAL, and furnish reprints, with a view to profit to the Association.

The above recommendations are based on the principle that the cost of the JOURNAL must not exceed $3.00 to each member of the Societies, and that the amount of matter must be restricted to that which can be published for that amount, and that the amount of matter at the disposition of any Society is in proportion to the amount of money paid by that Society to the Association.

Mr. Morehouse spoke at length in favor of the adoption by the Association of Engineering Societies of the above recommended rules, and by request the Secretary read a letter from Chairman J. B. Johnson to the members of the Board of Managers of the Association of Engineering Societies, under date of May 29, 1895, regarding certain matters concerning the JOURNAL.

The subject of the above report was discussed by Messrs. Ward, Morehouse, Condon, Mead, Reynolds, Liljencrantz, R. P. Brown and Thos. T. Johnston, and the following resolution was unanimously adopted:

"*Resolved*, That the recommendations for rules hereafter to be observed in the

publication of the JOURNAL, as presented to the Society this evening by the Board of Directors be concurred in by the Society, and that these recommended rules be forwarded to the Board of Managers of the Association of Engineering Societies as the expressed opinion of this Society, and that the representatives of this Society on the Board of Managers be instructed to present these rules to the Board of Managers for adoption."

The recommendation of the Board of Directors in regard to the Society badge was adopted.

It was voted that the thanks of the Society be extended to Mr. James R. Chapman and Mr. W. E. Baker, for courtesies extended to the Society on the occasion of its recent inspection trips to the power-house of the North Chicago Electric Transit Co., and over the line of the Metropolitan West Side Elevated Railroad, respectively.

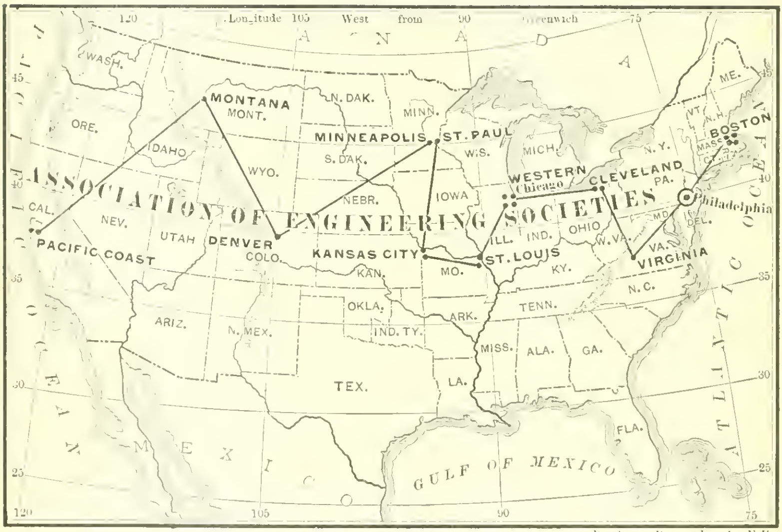
Prof. Hatch, Chairman of the Committee on Standard Gauges for Thickness of Metals, reported progress.

On motion it was *Resolved*, That the Board of Managers of the Association of Engineering Societies be requested to make to this Society a financial statement for the first quarter of the present year, and for each quarter thereafter, showing the cost of the JOURNAL, the number of members in each Society on the JOURNAL mailing list, the amount of money paid by each Society, and the amount any Society is delinquent.

It was voted that the regular meetings during the months of July and August be omitted.

Adjourned.

CHARLES J. RONEY, *Secretary*.



Bradley & Poates, Engr's, N.Y.

JOURNAL

OF THE

Association of Engineering Societies.

BOSTON. CLEVELAND. MINNEAPOLIS. ST. LOUIS.
CHICAGO. KANSAS CITY. MONTANA. ST. PAUL.
DENVER. VIRGINIA. SAN FRANCISCO.

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VOLUME XV.

July to December, 1895.

PUBLISHED BY

THE BOARD OF MANAGERS OF THE ASSOCIATION OF ENGINEERING SOCIETIES.

JOHN C. TRAUTWINE, JR., *Secretary*, 419 LOCUST STREET, PHILADELPHIA.

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VOL. XV, July–December, 1895.

The six numbers were dated as follows:

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No. 2, August.	No. 4, October.	No. 6, December.

ABBREVIATIONS.—P = Paper; D = Discussion; I = Illustrated.

Names of authors of papers, etc., are printed in *italics*.

ASSOCIATION OF ENGINEERING SOCIETIES.

Organized 1881.

VOL. XV. JULY, 1895. No. 1.

TIMBER-PRESERVING METHODS AND APPLIANCES.

Read before the Technical Society of the Pacific Coast, December 7, 1894.*

BY W. G. CURTIS, MEMBER OF THE SOCIETY.

THIS paper is intended less as a general review of wood-preserving appliances than as a description of a portable wood-preserving plant recently put into successful use on the Pacific System lines of the Southern Pacific Company, with a concise statement of the methods of using this plant for burnettizing ties. It presents to the Society also some brief notes on the modifications of the ordinary methods of creosoting timber, as practiced at the fixed creosoting plant in Oakland. These modifications were found necessary in order to creosote successfully Pacific Coast timbers, and they resulted in more satisfactory treatment of the timber, coupled with a decrease in the expense, as compared with ordinary methods.

The chief source of supply for railroad ties on the Pacific Coast is drawn from the California redwood timber region ; but the redwood timber, while very durable with respect to decay, is a soft timber and requires tie-plates for the best results under considerable traffic. Hence a large portion of the tie supply for Nevada, Utah, Northern California and Oregon can be most economically drawn from the pine and fir forests of Oregon and from the Sierra Nevada range in California. The supply points for this timber, however, are widely separated, the distance between the most easterly and the most northerly supply being 789 miles.

* Manuscript received May 31, 1895.—*Secretary, Ass'n of Eng. Socs.*

Intervening between these two points are high mountain ranges, the rise and fall of grades, westerly and northerly, between these two points being respectively 10,800 and 15,500 feet

The Southern Pacific Company's experience on their Atlantic System lines, as well as the results of some experiments made in California, demonstrates the economy of treating the pine and fir ties with zinc chloride.

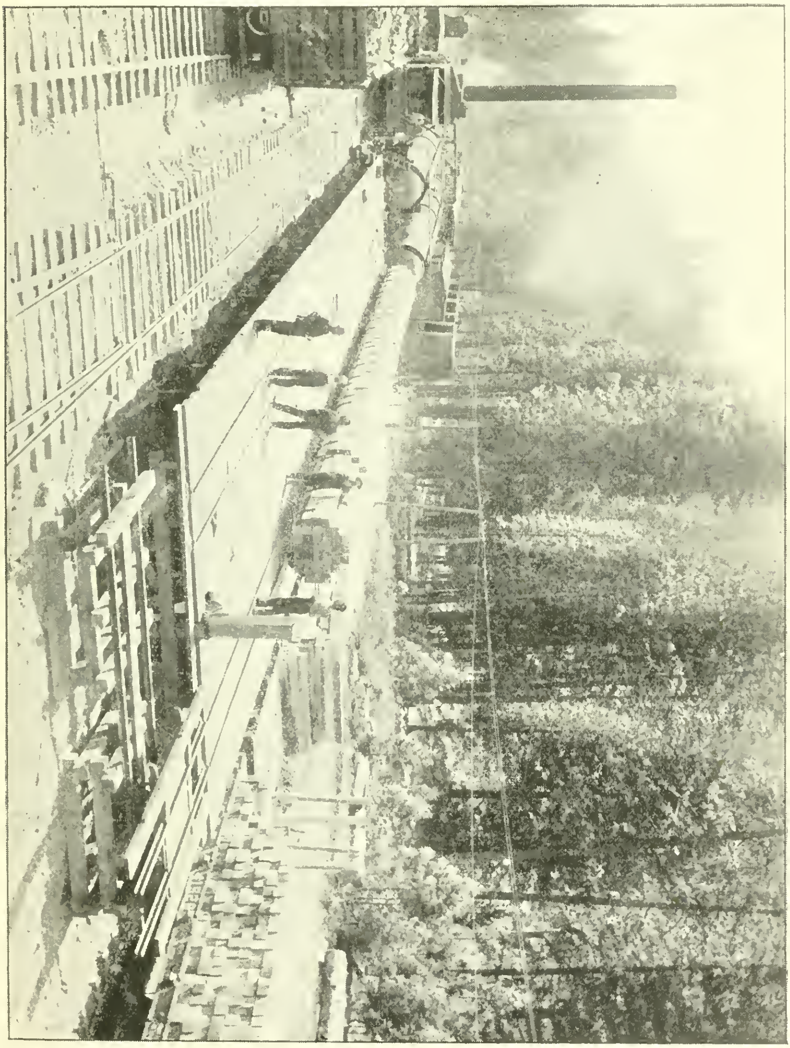
One wood-preserving plant, having a capacity for treating about 2,500 ties per twenty-four hours, is amply large to burnettize all of the ties required for the Southern Pacific lines naturally supplied with ties from the pine and fir forests. The conditions are such, however, that to locate the plant at a station, in the ordinary way, would involve a very great cost for hauling the ties from delivery points to the wood-preserving works and thence to point of use. The cost of four fixed plants, which would be required in order to reduce the cost of transportation to reasonable limits, was also prohibitory. These difficulties led to the design of a portable plant, which was put into operation in June, 1894. The photograph before you shows the plant as assembled for the treatment of ties by the burnettizing process at Chestnut Station, California.

The plant comprises all of the appliances essential for creosoting, burnettizing, and all of the ordinary wood-preserving processes; one car carrying two steam boilers, steam winch, tools, wire rope, etc., one car carrying superheater, measuring tank, force pump, air and circulating pump and condenser, two cars each carrying three wooden supply tanks for holding the preservative fluid, each tank having a capacity of 4,000 gallons, or a total capacity of 24,000 gallons, and two retorts, each six feet diameter by 114 feet long, divided into two sections, each section carried on two heavy car trucks. This plant, made up into a train of eight cars, made its initial journey from Sacramento, California, to Cornelius, Oregon, 706 miles, last May, passing over 3.3 per cent. grades and around the 14-degree curves of the Siskiyou Mountains without difficulty.

ARRANGEMENT OF TRACKS.

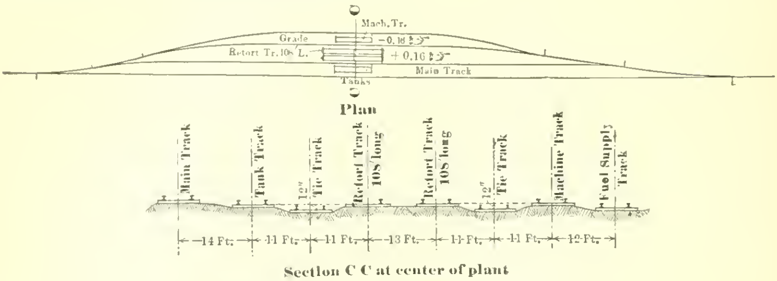
There are two arrangements of tracks used with this plant: First, when the bulk of the ties treated are for local distribution, and second, when the ties are, in the main, to be shipped to more or less distant points. In the first case, a through track is laid alongside of each retort; the tank and machinery cars are then placed on tracks beyond or outside of these tracks, ties are received on flat cars, loaded thence on the retort trucks for treatment, passed through the retorts and, on emergence at the further end of the retorts, are in position to unload on the same cars on which they were received; these flat cars having in the meantime

been moved along the through tracks, past the retorts, to their new position for receiving loads. In this plan of working, it is necessary to provide one empty flat car with every four loaded cars when received at the works, as the increased weight of ties by treatment necessitates the loading of fewer per car.



In the second case, it is not necessary to run the tracks through the works, as the ties are, in the main, received on flat cars and loaded for distribution in box cars, so that both loaded and unloaded cars are

switched in on their respective tracks, and afterwards pulled out in the direction from which the cars come.



TRACKS FOR PORTABLE PLANT.

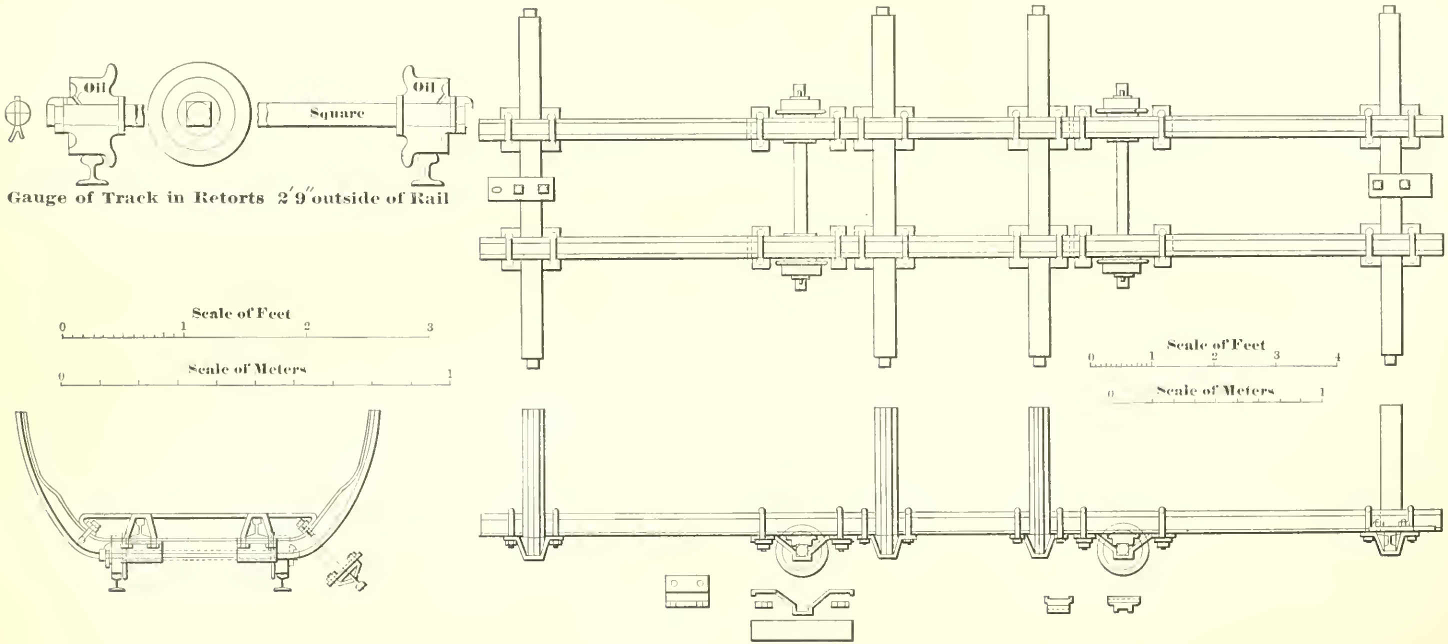
In both cases a slight grade is given to the loading and unloading tracks in such direction as is most convenient for moving the cars by hand, without necessitating the continuous use of a locomotive at the works.

SETTING UP.

The ground, tracks and foundations (made of tie blocking), having been prepared for the reception of the plant, the retorts are run into position, lined up and adjusted to height by jackscrews, which form part of the trucks supporting the retorts ; the trucks are then blocked up with steel wedges so as to take the weight off the springs, and the trucks at the center joint are blocked lengthwise. The end trucks are free to move endwise, so as to act as expansion rollers. The middle connection between the halves of each retort is then made, the tank and machinery cars are run into position and pipe connections made. All large pipe connections between machinery cars, tank cars and the retorts are made with ball and expansion joints ; the latter allow a play of some four feet, so that inequalities of track, both in height and distance, are provided for. The smokestack is raised with a gin pole and guyed ; the winch is placed in and below one of the end platforms and between the treating tracks, so that the engineer can see the charge as he works the winch. The wire cable for handling the charges is run under the platforms, from the winch to a snatch block at each end of the platforms, thence it returns on top of each platform.

PROCESS OF CHARGING AND HANDLING TIES.

The ties received at the works are placed on tracks adjoining the retort platforms, and are thence transferred directly to the retort trucks, being laid thereon in bunches cylindrical in form, bound together and to the trucks by small chains, "sticking" pieces of iron one-quarter to



RETORT TRUCKS FOR PORTABLE PLANT.

three-eighths of an inch thick being placed between each layer of ties. Two ropes called "pennants" are strung under the charge. These are wire ropes having an eye in each end, and are a little longer than a charge of ties. One end of a pennant is fastened to the foremost truck and one end of the other is fastened to the hindmost truck; the back rope from the winch is fastened to the former, and the pulling rope to the latter, so that the charge is hauled into the retorts by pulling on the hindmost truck, which pushes those ahead into the retort. The object of this is to dispense with couplings between trucks, and so economize room in the retorts. As the length of the retort is about the same as that of a charge of ties (fourteen lengths), it is necessary for the engineer to place the charge quite accurately. The object of the connection with the back rope from the winch is to enable the engineer to reverse and pull the charge slightly back in case it overruns, as occasionally happens, or to stop the load accurately by braking the back line. The charge having been run into the retort, the winch lines are unhooked from the pennants, and the ends of the latter thrown under the charge. The doors of the retorts are now closed and screwed up by hand wrenches. On the first screwing up of the retorts, not much trouble is taken to get them quite tight, as this can be better done later on when the vacuum is started in the retort.

METHOD OF BURNETTIZING TREATMENT FOR RAILROAD TIES.

(1) The charge is run in and the heads or doors closed and bolted up.

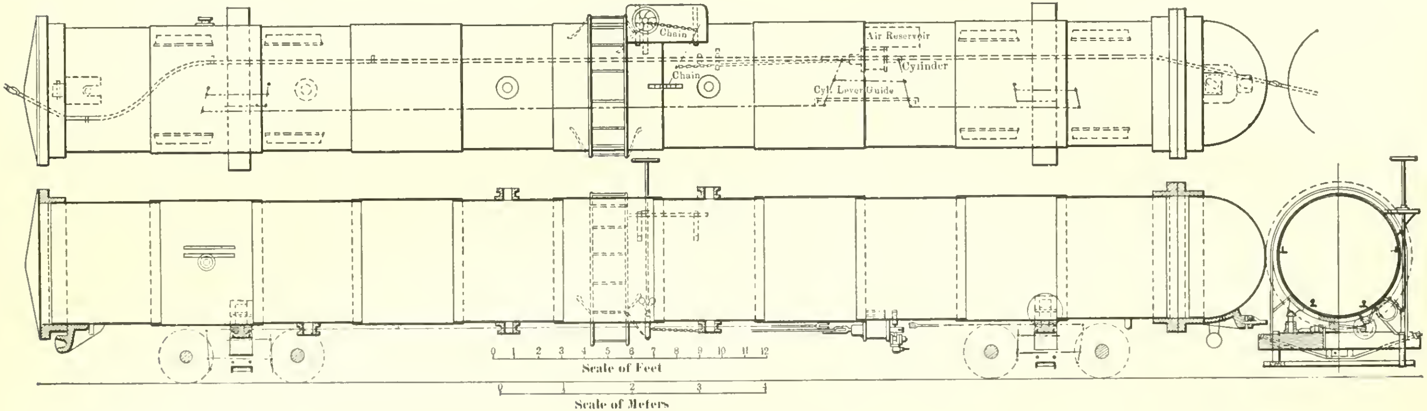
(2) A preliminary vacuum is begun; this is run up to about twenty inches. During this vacuum the doors are bolted up tightly. This vacuum process requires about ten minutes.

(3) Live steam is let in at about thirty pounds pressure, and continued for about four hours and a half. It is then blown off, requiring half an hour. During this steaming and blowing off, the retorts are drained.

(4) A second vacuum is created, of from twenty-two to twenty-six inches, which is maintained for about an hour.

(5) The retort is filled with the zinc chloride solution and pressure begun. This is continued until the required quantity of solution is injected into the ties.

(6) The surplus preservative fluid is drawn off, the doors opened, and the charge pulled out on the platform. Another charge, which has in the meantime been made ready, is immediately pulled into the same retort to undergo the same process. The treated ties are unloaded onto adjoining cars, the trucks pushed to a small transfer table at the end of the platform, transferred to the opposite track of



RETORT ON TRUCKS.

the same platform, and loaded with fresh ties to be run into the other retort for treatment.

Trucks sufficient for three charges of ties are used.

In steaming, live steam at a temperature of about 260° Fahr. is used, corresponding to a gauge pressure of about 20 pounds. Preservative fluid is injected at a temperature of about 150° Fahr. A maximum pressure of about 140 pounds is allowed in injection; with freshly cut ties, however, 120 pounds is not usually exceeded.

The total time of treatment averages about 8½ hours, and as the retorts are run nearly alternately, we get from noon one day to noon the following day five charges treated, or a total of 2,520 ties, 7 inches by 8 inches by 8 feet, per day of twenty-four hours If, however, all the ties are new or freshly cut, the time is reduced so as to get out six charges per day, or 3,024 ties in all per day of twenty-four hours.

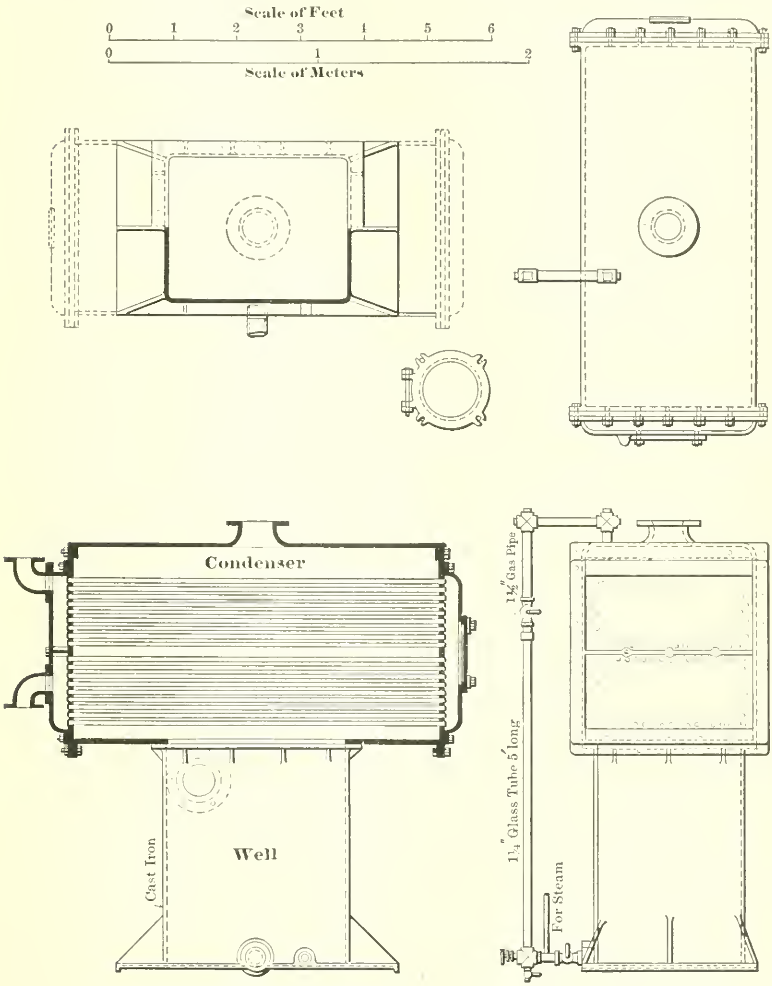
We find the time required varies greatly with the kind of timber and with the time during which the ties have been seasoning. California mountain pine, fir and spruce require less time than Oregon fir, and all timbers are more readily treated when freshly cut. An Oregon fir tie, seasoned in the air for two years, will take double the time for the treatment required for one freshly cut. Occasionally a close-grained, well-seasoned tie will not receive the preservative at all, the fluid penetrating into the sides only about half an inch.

Much attention has been given in this plant to providing means of watching the effect of the various steps in the process, so as to vary the treatment as the timber requires it. The retorts are provided with thermometers, the steam pipes with a pyrometer, and all tanks with gauges; the condenser is provided with a measuring well, all injection is from a gauged measuring tank, and sample ties are tested and reported from each batch, as noted further on. The principal blanks used for this and other reports are appended hereto.

The condensing apparatus consists of one set ot ordinary surface condensers (connected to the vacuum pipe and between the retorts and air-pump), which is over and supported upon a measuring well, into which all condensed saps and vapors flow, thus preserving a constant surface for condensation. The measuring well is provided with a glass gauge, and is of such dimensions that each foot of the glass gauge represents one-fourth of a pound of water extracted per cubic foot of timber. This well is so arranged that it can be emptied without stopping the air-pump. By this means any desired dryness of the timber may be accomplished with certainty. In the practical operation for the treatment of ties the extraction of moisture is stopped when the rate, as shown by the condenser gauge, is reduced to one pound of water per cubic foot per hour.

MIXING THE FLUID FOR USE.

Concentrated solution of zinc chloride, called "stock solution," as formerly purchased and now manufactured at the works, consists of about 43 per cent. pure zinc chloride, 2 per cent. of impurities (iron, aluminium, lead, etc.), and 55 per cent. of water. This is weighed out



SURFACE CONDENSER FOR PORTABLE PLANT.

and mixed in a small sump, with a proper proportion of water, thence pumped into the wooden supply tanks, tested with a Beaumé hydrometer, and, if necessary, a slight addition of either stock or water added, so that the liquid for use, called "standard solution," registers 2½°

Beaumé at 60° Fahr. The theoretical proportions for the desired standard solution, containing $1\frac{7}{10}$ per cent. pure zinc chloride, are 34.46 pounds stock of 43 per cent. zinc chloride to 100 gallons of pure water; but as there is much evaporation during the process the tendency of the standard solution is always to get stronger, so that, on a continuous run, there is added a certain proportion of water to allow for evaporation, or, what is the same thing, the quantity of zinc chloride to the gallon of water is reduced. Experience has taught us that about 27 pounds of zinc chloride stock solution per hundred gallons of water will keep our reserve solution (amount always in the supply tanks), together with that added for daily consumption, up to standard; but this is carefully watched and additions made one way or the other, as the case demands, so that the standard, when injected into the ties, is always $1\frac{7}{10}$ per cent. strong. The standard solution is heated to 156° Fahr. by turning steam through coils in bottom of tanks before being pumped into the charge.

TESTING TIES.

At intervals during the regular progress of the work and whenever any charge shows some change in the treatment as to necessary vacuum, time or amount of pressure, and after each change in kind, quality or dryness of timber, four sample ties are taken from a charge consisting of ties of average grain, one heaviest, one lightest and two average weight, and each tie is bored in the middle of its width and length with a one-inch bit. The first half inch of borings is thrown away, after which each inch of borings is preserved separately and designated as one inch, two inch, and three inch specimens. Each specimen is burned to an ash, over a gasoline jet, in a porcelain roasting dish, in contact with the air. The ashes are carefully collected in a platinum cup, distilled water added, with a slight excess of hydro-chloric acid, converting the zinc oxide into zinc chloride. It is then filtered into a test tube and the zinc hydrate thrown down with sodium carbonate, making a white flocculent precipitate. The liquid is then made up with distilled water to three drachms. The resulting milky liquid is compared with standard liquids in tubes of the same size as the test tubes, each tube containing three drachms. The standard liquids are graded to represent 6, 9, 12, 15, 18, 21 and 24 one-hundredths of a pound of zinc chloride per cubic foot of timber. As shown by the annexed table of proportionate parts (for which, as well as for much of the other data in this paper, I am indebted to our fellow-member, Mr. J. D. Isaacs, who has designed most all of the details of the plant and devised many improvements in the method of operation), the maximum of zinc chloride, per cubic foot of timber, desired is 24 one-hundredths of a pound. We are so certain of what we are doing by our methods

of observation that the tests are principally of value as checks. Recent tests have sometimes shown a minimum of 21 one-hundredths, but usually indicate the full amount. It is to be recollected that this minimum is from the geometric center of the tie. In such cases specimens taken nearer the ends show prescribed quantity. After boring, the ties are plugged with creosoted sticks turned to a tight fit, and shipped for use with the rest.

RECORDS.

A tabular record of each charge, giving all dates, times, durations, pressures and temperatures, is kept and charges numbered; a similar tabular record of all tests is kept and duplicates forwarded to headquarters. All ties are stamped on the ends, with the month and year of treatment.

We have found it economical and convenient to manufacture our own chloride of zinc stock solution. The apparatus is simple and inexpensive, and requires little attention. It consists of three lines of barrels arranged in steps. Beginning with the top and numbering them 1, 2, 3, 4, 5, and 6, they are arranged as follows:

No. 1, bottom 3 inches above top of No. 2, and has a lead spout emptying from the bottom into the top of No. 2.

No. 2, bottom 12 inches above bottom of No. 3, and has a lead pipe from near bottom to top of No. 3.

No. 3, bottom 6 inches above bottom of No. 4, and has a lead spout from near bottom to top of No. 4.

Nos. 4 and 5 same as No. 3, each emptying in same way into that below.

Each barrel is charged with about 600 pounds of zinc.

The carboys of muriatic acid are lifted to a platform beside barrel No. 1, through which the acid trickles rapidly, taking off, so to speak, its wire edge; that is, preventing violent action in barrel No. 2. In barrel No. 2 some ebullition takes place. The heavier, partially formed chloride sinks to the bottom, passes up through the lead pipe, and over into No. 3 and so on. We found it necessary to raise barrel No. 2 higher than the rest of the series, in order to get head for flow through its discharge pipe, some of the head being lost by the upward action of the hydrogen gas and steam. A continuous stream of zinc chloride, completely saturated as to the acid, runs from the pipe of No. 5, but to make certain, we run through No. 6; thence into storage barrels standing ready for use. The capacity of the chemical plant is about 5,000 pounds of stock solution per ten hours.

After each carboy of acid is emptied, one-eighth of its weight in water is thrown into barrel No. 1, which has the effect of cooling the

zinc, keeping down somewhat the ebullition in barrel No. 2, and supplying water evaporated. The loss of chlorine by evaporation is about one per cent. We find a better result by this process than by allowing the acid to simply stand on the zinc. The resulting zinc chloride stock solution has a density of 50° Beaume', and contains 43 per cent. of zinc chloride.

CREOSOTING, OR IMPREGNATION OF TIMBER WITH DEAD OIL OF COAL TAR.

The portable plant is arranged for creosoting timber also. This requires only the additional adjuncts of a superheater and steam coils in the retorts. Although we treat sawn timber with creosote, the bulk of the timber treated is in the form of round piles of Oregon fir. This material proved to be extremely difficult of treatment by any of the standard methods. The temperatures and pressures had to be forced, and the time required was very long (32 to 38 hours) to get any effective penetration. The piles after treatment were badly split and checked, and their strength seriously impaired.

In November, 1891, some experiments were undertaken with a view to overcoming these objectionable results. These experiments lead up to our present standard creosoting process, which closely corresponds with the methods advocated by Boulton ten years or more ago.

We merely boil the timber in the dead oil, and when sufficiently dry, inject the oil by pressure. In effect, we have returned to the open vat process tried fifty years ago, plus pressure in a closed retort. An open vat for boiling, followed by the introduction of the timber into a closed receptacle for injection, would answer the same purpose, but we find it more convenient to perform both parts of the process in the same retorts. In this process we use no vacuum, but pass the vapors during boiling through the surface condenser, leaving the outlet from the latter open to the air. The object in using a condenser is to enable us to measure the sap extracted from the timber, and to recover the lighter portions of the creosote carried over with the vapors of sap. Every foot in the measuring well of the condenser corresponds to ½ pound of water, or sap, per cubic foot of piles treated for average loads, and we find that the piles are practically dry when the condenser gauge shows 6 inches per hour. The same precautions as in burnettizing are used to follow the characteristics of each load and to vary the treatment accordingly.

The result of these changes in treatment has been most satisfactory. The time has been cut down to 12 to 14 hours per charge, as against our former time of 32 to 38 hours, and as against that required in present Eastern practice of 22 to 27 hours. Temperatures are reduced from 280° Fahr. to 240°; pressure reduced from 200 pounds to 120

pounds; fuel about one-half formerly used per charge. The timber is practically uninjured by the treatment. It is less checked than in ordinary air-seasoned timber, and whatever checking takes place is during the boiling, so that all checks are well filled with creosote.

In common with timber in burnettizing, the greener the wood is, the more easily it is impregnated with creosote. No difficulty is experienced in securing any desired penetration.

MEMORANDUM OF EXPERIENCE WITH TREATED AND UNTREATED TIES.

The treatment of ties with preservative substances was commenced in Europe as early as 1838, perhaps earlier. Of the many and various materials treated with on a large scale, only about four seem to have been used to any considerable extent. These were sulphate of copper, bi-chloride of mercury, chloride of zinc and creosote oil, and of these four only two seem to have survived for general use; namely, chloride of zinc and creosote. The former, on account of its comparative cheapness, is the one most commonly used.

The average results of tie preservation in Germany, where perhaps more careful records have been kept and investigations made than elsewhere, indicate that the life of railroad ties (so far as decay is concerned) is almost exactly doubled by preserving them.

In November, 1889, a small number of burnettized ties were put in the track, in a gravelly clay roadbed, near Tucson, Arizona, and an inspection just made, after four years and eleven months of service, shows that all of these burnettized ties are perfectly sound. At the same time and place, various untreated ties were put in the track adjoining the burnettized ties; of these, Truckee white fir has decayed to a depth of about ¼ of an inch on the under side; Truckee yellow pine has decayed to a depth of from 1 to 3 inches on the under side; Truckee red fir ½ inch decayed on under side; Truckee tamarack and Truckee sugar pine decayed from 1½ to 3 inches on under side; Shasta white fir and white yellow pine decayed on under side from 1 to 4 inches; Shasta red fir decayed on under side to a depth of from 1 to 2 inches; Shasta sugar pine decayed on under side to a depth of from 1½ to 2½ inches. The redwood ties, laid without tie-plates, under 50-pound rail, are perfectly sound, but the rail has cut down into them from 1 to 2 inches, indicating that the maximum life for such ties in such localities is between five and six years.

In December, 1889, some burnettized ties were laid in the San Joaquin Valley, near Turlock station, in a roadbed composed of sandy loam, under 60-pound rail. An inspection made March 1, 1894, after three years and four months of service, shows a slight decay on the

under side. Of the ties of similar timber, but untreated, put in the track at the same time the burnettized ties were laid, and adjoining them, the white and red fir were completely decayed and removed from the track in August, 1893, after three years and nine months of service. Of the yellow pine untreated ties, 90 per cent. were removed from the track after three years and nine months of service. Of the sugar pine, untreated, 90 per cent. were rotted down to the danger point and removed from the track after three years and four months of service. The tamarack, red and white fir, yellow pine and sugar pine, from the eastern slopes of the Sierras, near Truckee, untreated, are more or less badly decayed, after three years and four months of service, the indications being that the maximum life of the best of them will fall somewhere between four and five years. Of the 6 in. x 8 in. x 8 ft. redwood ties put in at the same time with very small tie-plates, all are sound after five years of service; the plates, which were entirely too small, have bent up considerably, but have not cut down into the ties more than $\frac{3}{16}$ of an inch. The 6 in. x 8 in. x 8 ft. redwood ties that were laid without tie-plates at the same time, are cut down under the rail to a depth of two inches, leaving only four inches of sound wood under the rail, and were removed from the track after about three years and nine months of service.

The service life of ordinary redwood ties (which, in ordinary roadbeds, will last many years without failure by decay), is measured not by time, but by the volume of tonnage passing over the rails; the speed as well as the weight being a factor in the wear in some proportion not well ascertained. Under average conditions of traffic, redwood ties eight inches wide and six inches thick, laid about 3,000 to the mile of track, and supporting 60-pound steel rail, will endure about 13,000,000 tons of cars and engines passing over the track; this amount of traffic being equal to nearly 30,000 trains, each consisting of a locomotive and tender weighing sixty tons, and fifteen cars weighing between 375 and 400 tons, or say an average of about sixteen trains with a locomotive and fifteen cars each per day for five years. The average endurance of 7 in. x 8 in. redwood ties is probably somewhere between 17,000,000 and 18,000,000 tons of traffic. Redwood ties are usually condemned as unserviceable when crushed down so as not to leave more than four inches of sound wood under the rail.

SOUTHERN PACIFIC COMPANY.

(Pacific System.)

WOOD PRESERVING WORKS.

Report of . . . . creosoted at . . . . , 189 .

Retort.		A.	B.	A.	B.
Charge number					
Date going in					
Date coming out					
Time . . .	Load in at				
	Filling begun at				
	Bath begun at				
	Refilling begun at				
	Pressure begun at				
	Pressure left off at				
	Load out at				
	Total time				
Temperature	When filled				
	At end of bath				
	When refilled				
	At end of pressure				
	When oil is let out				
	Of superheated steam				
Pressure . .	At beginning				
	At end				
Condensation	Per hour at beginning of bath .				
	Per hour at end of bath				
Pressure oil taken from					
Inches pumped from measuring tank					
Pile numbers inclusive					
Cubic feet timber					

(Signed)

Superintendent.

SOUTHERN PACIFIC COMPANY.

(Pacific System.)

WOOD PRESERVING WORKS..

Report of . . . . burnettized at . . . . , 189 .

Retort.		A.	B.	A.	B.
Charge number					
Date going in					
Date going out					
Time . . .	Load in at				
	Vacuum begun at				
	Live steam begun at				
	Vacuum begun at				
	Filling begun at				
	Pressure begun at				
	Pressure let off at				
	Load out at				
	Total time				
Temperature	At end of live steam				
	When filled				
	At end of pressure				
	When solution is let off				
Pressure . .	At beginning				
	At end				
Inches pumped from measuring tank*					
Number of ties in charge					
Number of cubic feet in charge					

* Each inch 25 gallons

(Signed)

Superintendent.

SOUTHERN PACIFIC COMPANY.

(Pacific System.)

WOOD PRESERVING WORKS.

Report of Inspection of Creosoted Piles and Timber made at . . . . , 189

The following creosoted piles (or timbers) have been inspected this day and passed or rejected as per statement below:

PILES.

No. of Pile.	Penetration.		Length of Pile.	Shipped in Car No.	Remarks.
	Butt.	Tip.			

TIMBER.

No. of Pieces.	Size.	Feet B. M	Minimum Penetration.	Shipped in Car No.	Remarks.

INSTRUCTIONS.—Inspect for penetration by boring two $\frac{1}{2}$-inch holes at a distance of from 10 to 15 feet from each end, according to length of stick; the two holes near each end to be diametrically opposite, and the pair on one end to be at right angles to that on the other. In special cases other holes may be bored. Care must be taken not to bore into a check. After inspection the holes must be plugged with wood saturated with creosote and turned to a driving fit.

SOUTHERN PACIFIC COMPANY.

(Pacific System.)

WOOD PRESERVING WORKS.

Report of tests of burnettized ties made at . . . . , 189

Charge number.					
Tie number.		Heavy.	Light.	Medium.	Medium.
Thickness of tie.					
Width "					
Length "					
Weight of "					
Zinc chloride per cu. ft.	Specimen 1 tie.				
	" 2 "				
	" 3 "				

(Signed)

Superintendent.

BURNETTIZING—TABLE OF PROPORTIONAL PARTS—OCTOBER, 1894.

Gallons Standard Solution	$= 1\frac{7}{10}$ per cent. $ZnCl_2$	1.	2.984	6.94	14.492	13.038	12.979	4.144	4.5	5.25	1.686
Pounds Stock "	= 43 " "	0.335	1.	2.326	4.856	4.369	4.349	1.389	1.508	1.759	0.565
" Pure Zinc Chloride	$= ZnCl_2$	0.144	0.43	1.	2.088	1.879	1.87	0.597	0.648	0.757	0.243
" " Metallic Zinc	= Zn	0.069	0.206	0.479	1.	0.9	0.896	0.286	0.311	0.362	0.116
" Zinc Dross or Skimmings	= 90 per cent. Zn	0.077	0.229	0.532	1.111	1.	0.995	0.318	0.345	0.403	0.129
" Pure Hydrochloric Acid Gas	= HCl	0.077	0.23	0.536	1.118	1.006	1.	0.32	0 347	0.405	0.13
" Commercial Muriatic Acid	= 32 per cent. HCl	0.241	0.719	1.675	3.494	3.144	3.125	1.	1.086	1.267	0.407
Number of Ties 6″ x 8″ x 8′		0.222	0.663	1.542	3 22	2.897	2.884	0.921	1.	1.165	0.375
" " " 7″ x 8″ x 8′		0.19	0.568	1.321	2.759	2.482	2.471	0.789	0.858	1.	0.321
Cubic Feet of Timber		0.593	1.768	4.112	8.587	7.725	7.591	2.455	$2\frac{2}{3}$	$3\frac{1}{9}$	1.

Standard Solution.	$2\frac{1}{2}$° Beaumé.	$1\frac{7}{10}$ p. c. Zinc Chloride.	1.017 Spec. Grav.	8.472 Weight per Gallon.	14,000 Gall. Reserve.

DISCUSSION.

Dr. Meyers.—Have any evil effects been noticed from cattle licking the ties and being poisoned by the zinc chloride?

Mr. Curtis.—I have never heard of any difficulty of that kind either from creosote or zinc chloride. In the mercury process there is a great deal of difficulty of this kind. It greatly affected the men employed. All sorts of expedients were resorted to in order to overcome it. They dressed in rubber clothes. And then, when laid in place, it was poisonous to animals.

Mr. Wagoner.—What takes place immediately after the vacuum has been made; does the sap run out of the ties?

Mr. Isaacs.—But very little sap comes out of the wood in the first vacuum. The principal object of the first vacuum is to get the air out of the retort so as to facilitate the introduction of steam, and also to enable us to close the doors tightly. It is hard to get the doors very tight unless there is a pressure of the air on the outside.

Dr. Meyers.—Do the borings show uniform impregnation clear to the center? How much zinc chloride is used per tie?

Mr. Isaacs.—For thorough impregnation of 7 x 8 x 8 inch ties there is required for the whole tie 0.75 pound of pure chloride of zinc. The impregnation is uniform clear to the center.

Dr. Meyers.—What is your experience with creosote in getting it uniformly distributed through the wood? In Germany they succeeded in forcing it clear through the wood, but the distribution was not uniform, and there were certain parts of the wood that would contain no creosote.

Mr. Curtis.—We do not seek to get the creosote clear through the wood. We are satisfied with a thorough impregnation in the outer part of the wood. But it is important that all the wood should be thoroughly seasoned and completely dried out. Our tests show a penetration of about three-quarters of an inch around the stick. From our experience thus far, this amount of impregnation seems to be quite ample to protect the timbers against the attacks of marine creatures. We have to be careful in treating the piles not to have them split and crack. A party came to us and spoke about a cluster of piles at the end of Clay Street wharf, and said the limnoria were eating them all up. We had the Harbor Commissioners pull one of the piles up and laid on the

wharf. I struck it with an ordinary hatchet and it split into two pieces the whole length. It had been cracked in the retort, but there was no evidence whatever of its being touched by the teredo or the limnoria.

DR. MEYERS.—Has your experience indicated any tendency for spikes to draw out of the wood on curves?

MR. CURTIS.—We have had no trouble of that kind. Our experience with preserved wood does not exceed five years, and our experiments have been on a rather small scale. It is the practice on our American roads to use tie-plates on curves, which overcomes that difficulty. Double-spiking the tie on the outer side is another expedient. Just what effect zinc chloride has on a spike, in the way of corrosion, I do not know.

MR. ISAACS.—The effect of zinc chloride on metals is to form a rust, but it seems to stop after it gets a little ways. We have experimented with almost every kind of paint in our retorts to prevent it, but without any success. A coating of rust will form about the thickness of a sheet of paper, and that is the end of it. It stays there until the plant is removed, and dries out, and then this coating is knocked off. When we use the retort again another coating will form. But we do not have any serious trouble from this source.

MR. WAGONER.—Where do you purchase the creosote, and where is it made?

MR. CURTIS.—What we use is brought from England. We have experimented with American creosote, but the latter is not near as good as the former. To be efficient it has to be of a certain standard, and the American creosote is not near up to the specifications. It should contain not less than eight per cent. of tar acid, which seems to be sufficient to coagulate the sap in the wood, and twenty-five per cent. of heavy oil. The heavy oil seems to be a very necessary part; it gets into the wood and corks it up, so to speak; it completely fills up the wood.

PROF. WING.—Have you any items as to the economy of using treated ties?

MR. CURTIS.—For pine ties it is about this way: In Oregon we buy them as low as 20 or 21 cents; in Northern California about 26 cents. All the evidence goes to show that by burnettizing them we can at least double their life. This process is now costing about 8 cents, and we expect to get it down as low as 7 cents for ties 7 x 8 x 8. So you see this is a good economic arrangement.

Mr. Vischer.—What is the relative cost of creosoting and burnettizing?

Mr. Curtis.—Creosoting is a great deal more expensive. The cost is pretty near ten to one for the wood actually treated, but there is not the amount of penetration in creosoting. We boil the wood in creosote oil until we have extracted pretty nearly all the moisture out of it—we cook it out, and then it is pretty well sterilized. Then we put this protection of creosote all around it—plug it up by the heavy oils, so the germs are not carried in by contact with the air or the water. If, on the contrary, the timber is not well seasoned before creosoting, and if the moisture is not thoroughly out of it, we have found quite a number of instances where the interior is completely rotted out, leaving a sound shell of creosoted wood around the outside. From our experience, if the work is thoroughly done, we believe piles will last a long time. They are protected and will last something in the same way as timbers in a covered bridge or in a house; they are protected against air and water.

Mr. Vischer.—The two processes of treatment are used for quite different purposes?

Mr Curtis.—Yes sir. We use creosote for piles, and for most of our timber work. We use it for everything in trestles up to the stringers, and sometimes creosote the stringers.

Mr. Wagoner.—Does not creosoting make the timbers more combustible?

Mr. Curtis.—I think it does. However, we have had nearly ten years' experience on the Atlantic system, but we do not know of a single fire that can be attributed to the fact that the timbers had been creosoted.

While I think of it, I will mention that common salt is a great preservative of wood. We have a stretch of track twelve miles long between Wadsworth and Ogden laid on bottom land on the edge of the great Salt Lake. The ground is soft, and there is a good deal of salt in it. The ties there are as bright and fresh as when they came out of the tree twenty-six years ago. Salt is very cheap on the Colorado desert; all we have to do in some places is to just shovel it up. There is a great deal of timber on the east of the desert, and we have been experimenting with jacketing the timber; making a hole all around the stick, and tamping salt in it. It requires renewal after every rainy season. We expect some very satisfactory results.

Mr. Vischer.—In the burnettizing process, what is the effect on the wood? Is the action of the chemicals purely astringent or is there a

filling up of the pores producing additional hardness due to the foreign matter?

Mr. Curtis.—I think it is partly a filling up and not purely an astringent action.

Mr. Isaacs.—The wood becomes a little more hard and a little more brittle. The tie is not quite so strong as before, but it is not sufficiently weakened to injure its service.

President Grunsky.—I am informed that Dr. Meyers has the results of some experiments in the vulcanizing process. We would be pleased to hear from him upon that subject.

Dr. Meyers.—In order to understand the vulcanizing process I think we must look at it from a chemical standpoint. The object of the process is to produce a change in the natural composition of the wood itself, instead of forcing antiseptic matter into it. Wood in its natural state is strongly antiseptic; it contains creosote, tannin, albumen, etc.; about sixty different chemicals in all. By the action of heat its natural constituents are changed. It produces changes in the pores of the wood, and a chemical change in the sap itself. In that process we endeavor to keep the large antiseptic qualities originally in the wood. We heat the wood to 200 and 300 degrees Fahrenheit, and maintain a pressure of about 150 pounds to the inch. The treatment takes from eight to twelve hours, depending upon the condition of the timber, and upon the timber itself. Dry, compressed, superheated air is circulated through it, and after the air becomes saturated with moisture, it is taken out and then reheated and passed through again. In that way considerable moisture is extracted from the wood. After the wood has undergone treatment its chemical composition is entirely different.

This experiment was tried in the East over ten years ago. At that time several hundred ties were placed on the elevated roads in New York City, in company with other ties that were not treated. I had the privilege of examining the treated ties about a year ago, and they were still doing good service, while the untreated ties, the Road Master told me, had rotted away and been removed.

The tests to which Prof. Wing refers are tests of strength, I believe. I know the process has been accused of weakening the wood, on account of the amount of heat used. Out of curiosity I made some tests at Columbia College of the strength of different kinds of woods after it had been vulcanized, and in its natural state before it was vulcanized, taking each piece from the same stick. The first test was made on Norway pine. It broke under a load of 3,000 pounds. It was placed on supports seven feet apart, and the pressure placed upon the center. The same piece untreated supported 2,680 pounds. That shows an increase

in strength of 11.94 per cent. Cypress broke under a load of 2,600 pounds; untreated, under a load of 1,860 pounds, an increase in strength of 39.8 per cent. I believe that cypress showed the greatest increase of strength.

Treated spruce broke under a load of 2,780 pounds, and untreated under 2,460 pounds; an increase in strength of a little over 13 per cent. Bass wood when treated supported a load of 2,840 pounds, and untreated 2,560 pounds; an increase of 10.9 per cent.

After that a larger number of tests were made, and in every case there was an added increase in strength.

Mr. Curtis.—Have you any figures as to the cost of the vulcanizing process?

Dr. Meyers.—I do not remember them. I know they had a great deal of timber to treat, more than they could take care of. I think they have two plants now, and are also building one in Washington. It is a patented process. It is rather new, and has been more experimental than otherwise. I think it is very much in its favor that the Manhattan Elevated road treats every piece of timber it uses on the road. That fact more than anything else led me to take an interest in it. Col. Hunt told me that they had tried every other process, and they had found this the most satisfactory.

Mr. Wagoner.—Have any experiments been made where the wood came in contact with the soil? Of course these ties were used on elevated structures.

Dr. Meyers.—They tried it in different kinds of soil. I know of a certain tunnel just out of New York City, where wood decays very rapidly, and said to be the worst place on the road for timber. They put in some treated timber from the South, which they said in its natural state was useless for railway construction, and it proved to be about as good as any wood. It seems to make a durable article out of an otherwise uselesss thing. I examined these ties myself, after they had been in the ground for six years. They still retained a strong odor of the wood, and were in very good condition.

The pieces that I tested as to strength were cut, I think, by the Bell Telephone Company, and were in the shape used for cross-poles. We simply cut them in two halves lengthwise; one piece we treated, and the other did not.

Mr. Isaacs.—There is one point in regard to creosoting that I think has some bearing on this vulcanizing process. Our theory is to first coagulate the albumen of the wood by heat, and then inject the creosote. Creosote contains carbolic acid, and other substances. During this process a filtration takes place. The carbolic acid goes in first, and that is followed by napthaline, which is of itself a pretty good anti-

septic, and is permanent. If we used carbolic acid and nothing else, in a short time the piles would be no longer preserved. This filtration keeps the heavy oils near the surface, and forms an exterior coat which is impervious to water, and prevents the washing out of the napthaline and the coagulated albumen. It seems to me that one of the difficulties in this vulcanizing process is lack of sufficient material to form wood creosote. The use of wood creosote, by the way, has never been a success. There is sufficient material in the wood to form a good wood creosote for the timber, or tie, but it is not in the right place—that is to say, the heavy portions, the napthaline portions, and the other constituents are all mixed up together. As far as we have investigated, our arrangement of these materials is about right for the purpose intended.

Dr. Meyers.—What is the temperature of the creosoting process?

Mr. Isaacs.—About 250 degrees. I have tried 350 degrees without apparently injuring the wood at all, but not with pressure.

Mr. Vischer.—The impression seems to prevail among the men using the ordinary kiln-drying process with redwood, that it is an easy matter to use too much heat, and thereby make the wood brittle.

Dr. Meyers.—It seems that under a very high pressure the wood does not seem to burn ; it seems to prevent ignition. It seems it would be an easy matter to heat the wood without the presence of creosote first, without the pressure of air.

Mr. Isaacs.—We found if we heated it without creosoting, it took a long time to dry. If a vacuum is formed to help the drying you deprive the timber of any means of getting heat except radiated heat.

Dr. Meyers.—In the vulcanizing process they use pressure.

Mr. Wagoner.—What purpose does the pressure serve?

Dr. Meyers.—Pressure seems to make the chemical change in the wood caused by heat more uniform through the wood ; it also seems to prevent the liquids from escaping, and keeps them more in a liquid form instead of a gaseous form. I have often wondered if it was not the mere heating of the wood that preserved it ; just as in boiling an egg, the boiling coagulates the albumen and preserves it.

Mr. Curtis.—The present difficulty in heating wood, if the air surrounds it, is a tendency to check the wood and split it.

Mr. Wagoner.—I should say the pressure was to prevent evaporation.

Mr. Isaacs.—The pressure is to keep the moisture in the wood while this process is going on.

COST OF STEAM AND WATER POWER IN MONTANA.

Read before the Montana Society of Civil Engineers, June 8, 1895.*

By M. S. Parker, Member of the Society, and of the American Society of Civil Engineers.

The rapid development of mechanical appliances for the usage of electrical energy is working a wonderful revolution in the motive power of the world. The controlling of steam for motive power is the result of modern investigation, almost within the memory of the oldest inhabitant. Close upon the heels of this discovery and its development to the full limit of perfection, comes this newly discovered motive power, electricity, and with each day are born new ideas, almost inspired ideas, one might say, suggesting more improved methods for controlling this mysterious, unanalyzed, irresistible, powerful agent. Who can predict what the next century will bring forth in the use of this mysterious fluid? Judging from the progress of investigation for the past quarter of this century, the result will far exceed the most visionary views of the present enthusiasts. Engineers are aware of the progress being made in the generation and transmission of electricity for power purposes. The civil engineer is not generally an electrician, on the contrary, his knowledge is more general than special. The civil and electrical engineers, however, are closely allied, and must, in the future, work hand in hand together. The electrical transmission for power is fast bringing all the hitherto obscure water powers of the world into commercial importance. The day is not far distant when all the available water power of the United States, in 'fact, of the world, will be utilized to its fullest capacity.

I need not go into detail as to progress being made in this direction. This is known to all engineers who are keeping abreast of the times.

Montana has extensive opportunities for the development of water power within her borders, and the next decade should show vast strides along the lines of its development.

The writer has given much attention during the past five years to the opportunities for developing water power in Montana, particularly along the course of the Missouri River, and must admit that the possibilities are beyond his most sanguine expectations, both as to cost and quantity of power. The development at Great Falls, Montana, with which the writer has been connected since its inception, is but in its infancy. There is no reason why, in the near future, every town and mining camp in Montana should not have its electric power station supplying all

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power for lights, street railways, and the running of machinery for all purposes. In the opinion of the writer, steam must give way to electricity, and that soon, especially in Montana, the State ranking first in the country for its available water power. Its cheapness alone will force the result. Coal consumers' boilers will have to give way to water wheels. The percentage of loss in transmission I will not go into in detail in this paper, sufficient to say that the percentage of loss in electrical transmission, within twenty miles of distance, is not greater than the ordinary loss by direct rope transmission from power station to works, 1,000 feet distant. Late-long distance transmission of electricity for power experiments are highly satisfactory. The object of this paper is simply to lay before the Society a few tables prepared by the writer showing relative cost of steam power as compared with water power in Montana. Such data is constantly needed by the engineer, and it is a duty that one owes to the profession to record whatever may be of interest to its members. The following tables will explain themselves:

TABLE NO. 1.

COMPOUND ENGINE.—ALL STEAM CHARGED TO POWER.

Table showing ordinary running daily and yearly expenses 500 H. P. Plant.

Cost of Coal per long ton 2240 lbs.		Pounds of coal per H. P. per hour.	Cost of coal per H. P. per day.	Boiler attendance per H. P. per day.	Engine attendance per H. P. per day.	Oil waste and supplies per H. P. per day.	Total daily expense 1 H. P.	Total yearly expense, 365 days, 1 H. P.
			Cents.	Cents.	Cents.	Cents.	Cents.	
$1.75	10¼ hours per day	5.6	4.48	0.6	0.75	0.3	6.13	$22.37
	24 " " "	5.6	10.47	1.54	1.50	0.7	14.21	51.86
$2.00	10¼ " " "	5.6	5.17	0.6	0.75	0.3	6.82	24.89
	24 " " "	5.6	12.09	1.54	1.50	0.7	15.83	57.78
$3.00	10¼ " " "	5.6	7.46	0.6	0.75	0.3	9.11	33.25
	24 " " "	5.6	16.47	1.54	1.50	0.7	20.21	73.76
$4.00	10¼ " " "	5.6	10.33	0.6	0.75	0.3	11.98	42.93
	24 " " "	5.6	24.19	1.54	1.50	0.7	27.93	101.94

This table is based on the consumption of Sand Coulee, Montana, *slack coal*, tested at the Silver Smelter at Great Falls, Montana, on twenty-four hour-run purposely, without extra precaution, to ascertain amount of coal consumed, using three-quarter-inch grate bars, 60 x 16 feet tubular boilers. Result: $5\frac{6}{10}$ lbs. per hour per horse-power. A 200-horse-power compound engine at Silver Smelter costs $64 per horse-power per year, as I was informed by an engineer who made the estimate two or three years since. I think the figures about right for present conditions. The smaller the horse-power of the plant the larger the expense per horse-power proportionately.

TABLE No. 2.

500 H. P. Plant.

Showing Cost of Steam Plant per H. P. to Charge to Power.

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
Engine Compound. All Steam charged to Power.	Engine and Piping.	Engine House.	Engine Foundation.		Total Cost Engine Plant.	Depreciation, 4 per cent.	Repairs, 2 per cent.	Interest, 8 per cent.	Taxation, 1½ per ct. ¾ Cost.	Insurance, 0.5 per cent.	Total, Columns 7, 8, 9, 10 and 11.	Boiler Complete.	Boiler House.	Chimneys and Flues.	Total Cost, Boiler Plant.	Depreciation, 5 per cent.	Repairs, 2 per cent.	Interest, 8 per cent.	Taxation, 1½ per ct. ¾ Cost.	Insurance, 0.5 per cent.	Totals of Columns 17, 18, 19, 20 and 21.	Total Yearly Expenses. Columns 12 and 22.
	$25 00	$8.00	$7.00		$40.00	$1.60	$0.80	$3.20	$0.45	$1.65	$7.70	$9.33	$2.92	$6.11	$18.36	$0.918	$0 367	$1.468	$0.207	$0.092	$3.052	$10.752

This table is to be used in connection with Table No. 1. Add the total in last column ($10.752) to total as shown in Table No. 1 for the total yearly expense of one horse-power on 500 H. P. plant. Columns 6 and 16, Table No. 2, give cost of plant per H. P. ($40.00 + $18.36 = $58.36). The prices on which table is based, *i. e.*, Great Falls, Mont., prices, are applicable closely to all parts of Montana.

TABLE No. 3.

SHOWING YEARLY EXPENSE OF WATER POWER PER H. P. ON WHEEL SHAFT.

HORSE-POWER.	1	2	3	4	5	6		
	Original Cost.	Interest on Original Cost—8 per cent.	Tax, $1\frac{1}{2}$ per cent. $\frac{3}{4}$ Cost.	Depreciation, 2 per cent.	Repairs, 2 per cent.	24 Hours per Day. Total Running Expenses per H. P.	Totals of Columns 2, 3, 4, 5 and 6.	Totals of Fixed Charges.
3,636 net H. P. . . .	$52.00	$4.16	$0.78	$1.04	$1.04	$.255	$9.57	$34.796
7,200 net H. P. . . .	35.00	2.80	0.525	0.70	0.70	2.55	7.27½	52.370

The above table is arranged from the writer's note-book. Number of horse-power and cost from actual verified estimates in two instances that the writer has planned.

In conclusion it may not be amiss to mention some of the noted water-powers of the country, giving their capacity and charges for power:

Holyoke, Mass., ...	12,260	H. P.	Gross Power
Manchester, N. H., ...	12,000	"	"
Lowell, Mass., ...	11,845	"	"
Lewiston, Maine, ...	11,000	"	"
Lawrence, Mass., ...	10,900	"	"
Cohoes, N. Y., ...	6,560	"	"
Minneapolis, Minn., ...	9,200	"	"
Great Falls, Mont., ...			
Black Eagle Falls, ...	18,200	"	"
Niagara Falls, ...	100,000	"	"

These amounts are closely the minimum figures for power—gross horse-power. The net power is about 20 per cent. less on the wheel shaft.

Various charges for water-power at Manchester, Lowell, Lawrence, Minneapolis; a few places from the above list are as follows: Manchester, about $300.00 per mill power for original purchase, $2.00 per day for surplus per mill power. Lowell, about $300.00 per mill power for original purchase, $2.00 per day per mill power during back water, $4.00 per day per mill power for surplus under 40 per cent., $10.00 per day per mill power over 40 per cent. and under 50 per cent., $20.00 per day per mill power for surplus over 50 per cent., $75.00 per day per mill power for any excess over limitation, 100 per cent. Lawrence, about $300.00 per mill power for original purchase, and about $1,200 for new

leases per mill power. At the above-named places a mill power is equivalent to 65 horse-power on the wheel shaft. The charges for surplus water in the before-mentioned instances amounts to about the same thing at the different places. At Minneapolis, a more modern water-power, the mill power is equivalent to 50 horse-power on the wheel shaft and is charged for at the rate of $1,200 per mill power. The charges for power at all the above-mentioned places is about the same for new leases, and amounts to nearly $25.00 per horse-power per year for 24-hour runs. I learn that the Niagara Power Company has leased power in large amounts as low as $8.00 per horse-power per year in 5,000 horse-power leases. The Eastern powers are based upon ten hours per day run.

The surplus is the accumulation of water in storage pond, enabling the extra running of wheels. With the figures for cost of steam power at hand it is a simple calculation to determine as to the worth of water-power. The original cost of development of the power together with the resulting power, determines its commercial value as compared with steam.

WOODEN BRIDGE CONSTRUCTION ON THE BOSTON AND MAINE RAILROAD.

Read before the Boston Society of Civil Engineers, May 15, 1895.*

By J. Parker Snow, Member of the Society.†

The subject of iron and steel bridges has been quite extensively written up in our technical literature during recent years, but wooden bridges are seldom discussed, and when mentioned, are generally treated as temporary structures or excuses offered for their use. The building of such bridges is, however, a live business on the Boston and Maine Railroad, although the impression seems to be prevalent in many quarters that such construction is obsolete and out of fashion.

This paper is offered to describe the present practice in wooden bridge construction on the above-named railroad, and if not considered as in line with present approved practice elsewhere, may at least have some interest as a history of one branch of the bridge-building art.

On the system operated by the Boston and Maine there are 1,085 wooden bridges of all kinds in a total of 1,561. This number covers overhead as well as track bridges and includes everything of 6 feet clear opening and upwards, except stone box culverts. The proportion of wooden bridges grows less each year, although more than half of the new structures built to replace old bridges are built of wood.

The types most commonly used for new work are pile trestles, plain stringer bridges, compound stringers made of timbers keyed together to get greater depth than is possible with single sticks, pony trusses of the Queen post and Howe type, and Town lattice bridges. At the present prices of iron bridges Howe trusses of considerable span, if built in first-class shape of Southern pine timber, cost almost exactly the same as iron ones and consequently are practically ruled out. A considerable number of stringers trussed with rods beneath are in existence, but are seldom built at the present time.

Spruce timber is used for all parts of Town lattice bridges, and for caps, stringers and ties in many trestles and plain stringer bridges on Northern lines. On lines south of Central New Hampshire, however, Southern pine is almost invariably used. Spruce is sufficiently durable when roofed in, and on account of its lightness is much better than Southern pine for lattice trusses, but its softness and tendency to warp and the difficulty in getting sticks of sufficient length make it unsuited for Howe truss work of magnitude. For bottom chords of lattice bridges

* Manuscript received June 4, 1895.—*Secretary, Ass'n of Eng. Socs.*

† This paper was printed in the Journal for June, 1895, but with some of the matter transposed. It is accordingly reprinted here.—*Secretary, Ass'n of Eng. Socs.*

of over 100 feet span, recourse must be had to Southern pine also on account of the difficulty in getting spruce of the requisite length. Tamarack, oak and chestnut are used for piles in trestles.

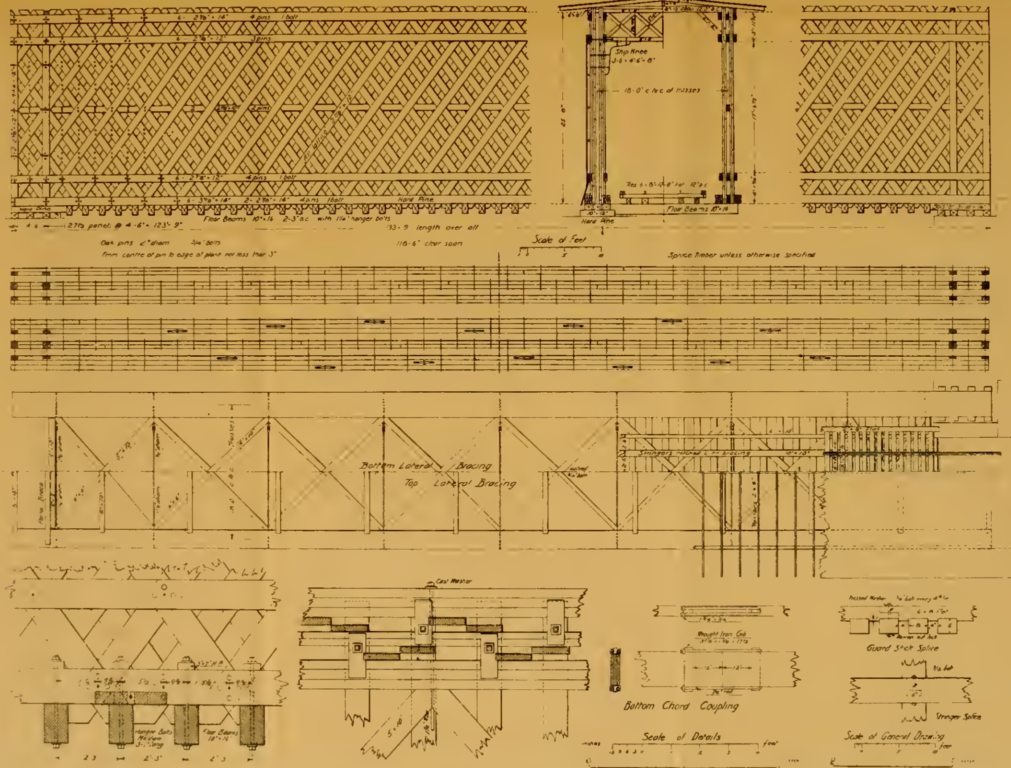
The life of sawed spruce exposed to the weather is but about six or seven years. Southern long-leaf pine of prime quality in similar conditions is reliable for twelve to fourteen years. When covered in and well ventilated and kept free from accumulations of dirt, either timber will last forty to fifty years. Sawed chestnut for ties, stringers, etc., is about intermediate in durability between spruce and hard pine. It has been used for bridge timber on the Southern lines of the system considerably in years past, but is not so used now and is not recommended.

Tamarack piles in dry land trestles will last eight to ten years, chestnut and oak of good quality fifteen to twenty.

The loads used in calculating new wooden bridges are somewhat lighter than the standard used for those of iron. It is thought that wooden bridges are necessarily of a less permanent character than iron ones and that within their natural life the weight of rolling stock will not increase so much above what it is at present as may occur in the life of an iron bridge; again, if wooden bridges are found to be too light for future loads, they can be strengthened, or supported on trestle bents much better than iron ones, and a wooden bridge, like a piece of masonry, will give abundant notice of distress before it will fail entirely. The governing reason for building wooden bridges instead of iron ones altogether is, of course, their less first cost, and if the full standard load for iron bridges was used in designing them this element of advantage would be reduced and they would be no more serviceable or satisfactory for present use than if designed for the lighter load. The load used is a train of consolidation engines weighing, each, with tender, 172,000 pounds, with 24,000 pounds on each driving axle, or 80,000 pounds on two axles, seven feet apart. This is somewhat in excess of engines in use at present on this system, and although considerably lighter than the load used in designing iron bridges, the considerations given above seem sufficient to justify its use.

The usual unit strains used are, for Southern pine 1,000 pounds per square inch direct tension and 800 compression; the latter, of course, reduced for ratio of length to diameter. For spruce this unit is taken at 650 compression and 800 tension. For fiber strain in stringers and beams the unit is 1,200 pounds per square inch for both hard pine and spruce. The reason for adopting this figure for spruce is that in exposed situations, as is the case with stringers, the life of spruce is so short that it is a waste of material to provide for the much talked about increase in engine loads, and while sound, this unit gives a very satisfactory bridge. For combined transverse and longitudinal strain two-thirds of the former is added to the latter and 800 pounds used as the unit. Longitudinal shear-

J. PARKER SNOW, WOODEN BRIDGE CONSTRUCTION ON BOSTON AND MAINE R. R.



ing is kept below 80 pounds per inch and transverse crushing on hard pine from 350 to 400 pounds per square inch, depending on whether the whole width of the stick is covered or only a small area.

These unit strains are used for new work; an old bridge will, however, stand up and carry its load when the computed strains in some parts are very high. Of the three classes of bridges built twenty years ago, iron pin, iron riveted and wooden, all of which figure equally near the danger limit, common prudence will select the pin bridge as the first one to be removed, the riveted one next and the wooden one, if sound, last.

The cost of bridges for single track of 120 feet span will compare something as follows:—Iron $5,300. Howe truss of Southern pine and iron angle blocks $5,000, and spruce lattice $3,500. Below this span, the advantage of wooden bridges over iron ones in point of cost will increase and above it the advantage rapidly reduces to nothing.

The standard spacing of bents in pile trestle bridges is 15 feet. Solid caps drift-bolted to the piles and girder caps with riders are used indiscriminately, the former being the cheaper and the latter making the most rigid structure. The stringers used on these trestles are for single track, two 8″ x 16″ under each rail and one of the same dimensions on each side placed 10 feet apart from outside to outside. The stringer sticks are 30 feet long, laid to break joints; the two sticks under each rail are spaced 2″ apart by cast iron spool separators and ¾″ bolts, four at each cap. The stringers are secured to the caps by drift bolts. The floor consists of ties 6″ x 8″ x 12 feet long, laid 4″ apart in the clear. Tie spacers 6″ x 8″ are placed flat on the ends of these, notched down one inch and bolted to every fourth tie. These bolts have a round burr washer under the head on top and a Warren nutlock for washer at the lower end. The floor is kept in line by occasional lining spikes or drift bolts through the ties into the side stringer.

The tie floor above described is standard for all wooden bridges; it is shown in cross-section Fig. 1. In designing, the ties are considered as

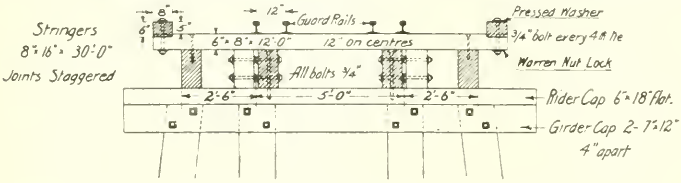


FIG. 1. STANDARD TRESTLE; 15 FT. BENT.

distributing the load so that 80 per cent. is carried by the main stringers and 20 per cent. by the side ones. The continuity of the stringer sticks over two spans is considered as reducing the moment of the load at the centre of span by 10 to 12 per cent.

Plain stringer bridges are built the same as above described for trestles, except as the stringers do not have the advantage of continuity over supports, the sections must be larger for similar spans. The depths of the sticks should not be less than $\frac{1}{12}$ to $\frac{1}{14}$ the span.

When the span becomes too great for merchantable depths of timber, or convenient thicknesses, recourse is had to keyed stringers. These are made by placing one stick on top of another and framing cast-iron keys between them, as shown in Fig. 2. A vertical bolt at each key prevents the timbers from separating.

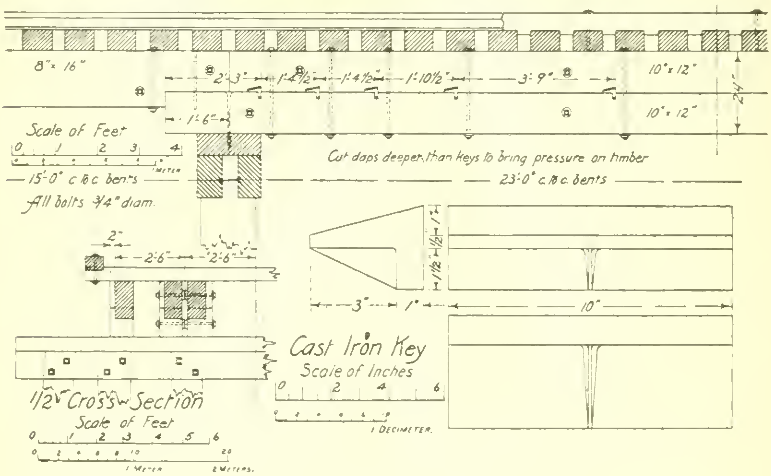


FIG. 2.

These keys are proportioned for the longitudinal shear, and hence the total depth of the compound stick can be used in computing its moment of resistance. The keys are cut $1\frac{1}{2}''$ into each upper and lower stick, and an attempt is made to distribute them according to the intensity of the shearing strain; but near the ends of the stringer a strict adherence to this requirement would bring them so near together in some cases that the daps might split out. With notches $1\frac{1}{2}''$ deep, it is desirable that they should be at least $18''$ apart. The quantity of longitudinal shear at the neutral axis, between any point and the end of a beam, is a function of the fiber strain at that point; being equal to $\frac{b.d.f.}{4}$ when $b.$ is the breadth, $d.$ the depth and $f.$ the extreme fiber strain. A convenient way to locate the position of the keys is to draw a line the ordinates of which represent the moment of the load and lay off to some convenient scale, $\frac{b.d.f.}{4}$ as an inclined ordinate at the center of this curve. Now, beginning at the base, space off on this inclined line the value

of each key, and draw horizontals through the points of division; these horizontals will cut the moment curve into spaces showing the proper field for each key. The friction between the two sticks, induced by the load and by the grip of the vertical bolts, helps to resist the longitudinal shear, and a proper proportion can be added to the value of the key when spacing off the inclined ordinate.

These stringers require considerably more material than trusses of equal strength, but the labor on them is small and they can be put in place and prepared for the passage of trains in much less time than trusses. This latter quality is of great importance, and should be given more attention by bridge designers than it generally receives. This style of bridge works in with the ordinary trestle spans very conveniently when it is desired to make a wide opening for a runway for ice or logs, or for a highway underpass. The lower stick of the compound stringer is extended beyond the upper one to furnish a seat for the regular stringers of adjacent bents. In cases, too, where the trestle bents are high and expensive it will lessen the cost of the structure to make alternate spans compound or keyed stringers. This style of bridge is available up to clear spans of 30 feet.

Pony trusses are used for spans between 30 and 60 feet, generally of the Howe type. For overhead highway bridges requiring trusses modified pony Howe trusses are used almost exclusively. For these latter and for track bridges it is altogether better to use floor beams, distributed along the chord about 2½ feet apart, rather than to concentrate the load at panel points by means of stringers carrying the load to large floor beams, as is done in iron bridges, and it is generally best to hang the floor beams below the chord. If the plank floor of highway bridges is laid directly on these cross floor beams it brings the plank parallel to the line of travel; this is considered objectionable, and hence longitudinal spiking joist or stringers, 4 to 6 inches thick, are laid on the cross floor beams and the plank spiked to these. On bridges carrying light traffic a single 3″ floor is used, but where the travel is heavy it is economical to use a double floor, generally 2″ below and 3″ for wearing surface. The under plank lengthens the life of the floor very considerably by keeping it safe for a long time after the corners of the upper plank have worn through.

Railroad bridges of this class should always have the top chords stayed against side motion, as shown in Fig. 3, and it pays to protect the trusses from the weather by sheathing and roofing them in.

For spans greater than is desirable for pony trusses the Town lattice built mostly of spruce is our only resource. As before stated, Howe trusses of Southern pine cost almost as much as iron bridges at present prices. Spruce, the only available timber growing in the region in

which these bridges are used, is not well adapted to Howe truss work, but is excellent for lattice bridges. This style of bridge seems never to have been developed to much extent outside of New England, and it is fre-

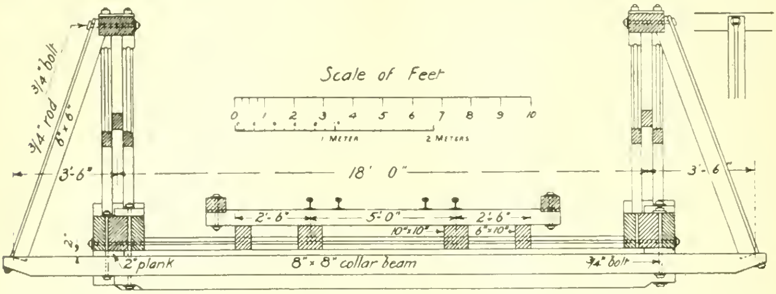


FIG. 3. SWAY BRACING FOR PONY TRUSSES.

quently referred to as peculiarly unscientific and wasteful of timber. It is, however, the best of the purely wooden bridges, and its present survival here and its economy over all other types disproves its wastefulness. These trusses should always be built double, that is, with two webs like a box girder. Single web trusses can be made strong enough up to 80 feet span, but they do not stand so steadily or keep in line so well as those with double webs. The distance between the webs is immaterial, but is generally made equal to the thickness of two chord plank, from 6 to 8 inches. Outside of the webs, it is not deemed advisable to use more than three thicknesses of plank on each side; this confines the chord to 8 planks, and as this is generally not sufficient to give the requisite strength, a second chord is added at the second web intersection. These second chords serve not only to carry chord strain, but also to stiffen the diagonals and to assist the outer chords to distribute the shear between the tension and compression members of the web.

The chord strength of these trusses is computed by assuming the distance between the centers of outer chords as the effective strain depth of the truss, and reducing the section of the inner chords in the ratio of the squares of their distances from the neutral axis. In the case shown on the inset this ratio would be nine-sixteenths. In several bridges of this type now standing on the Boston and Maine road, built in former years, there are three sets of chords, but the third chord has but little theoretical value, and judging by the amount that the joints are pulled they assist but little in carrying the chord strain. The proper arrangement of the breaks in the planks of the lower chord affects the strength of the whole much the same as the arrangement of eyebars affects the strength of pins in an iron bridge.

In bridges of 125 feet span and upwards it becomes necessary to fasten the abutting ends of the chord plank together and the device

shown on the inset is used for this purpose. The gib-bars are wrought iron, varying in section with the thickness and width of plank to be joined; hexagon nuts are used on the yoke rods so as to necessitate as little cutting of the chord stick as possible. A ribbon is sometimes put between the webs at the middle height of the truss, as shown in the inset, with the idea of stiffening the web and preventing vibration.

The shear is assumed to be uniformly distributed over all the web planks cut in a given section. The members are so thoroughly pinned together that they cannot possibly act as single independent systems to be separately calculated as is advocated in some text-books, but the strain must be equalized throughout a vertical section much as would be the case with a solid web.

A lattice truss should extend well on to the masonry. For reasons connected with the proper construction of the floor this extension on the abutment should be about one and one-half panels; a solid bolster should be placed under the chord for this distance and under this should be the cross wall blocking. The compression diagonals near the end of the truss deliver their shear to very short tension members; the fastenings of these do not seem to be able to carry the load delivered to them, and the bolster is needed to help take the thrust of the compression members direct. Many old bridges built probably without much knowledge where the maximum shear occurs have failed by having the bottom chord split down or literally sheared at the edge of the wall plate by this action. Proper bolsters would have largely prevented this. It is the custom now to put solid posts between the webs at the end and second panel points extending the whole depth of the truss. These cut through the two middle plank of the chords and would endanger shearing the bottom chord if the bolster did not extend beyond the cut-off. These solid posts furnish a substantial support to pin the short ties to and to receive the compression members which do not reach the bottom chord. None of the trusses built in this way have shown indications of weakness in the way explained above. The panels should be between 4 feet and 4½ feet and the web plank should be given inclinations of nearly 60° with the horizontal.

The pins used in these bridges are 2″ oak. They should be of well-seasoned timber, and should be carefully turned so as to drive tightly when the bridge is erected. Much depends on the pins. In old and weak bridges the pins are frequently found much distorted. In heavy trusses all plank must be at least 12″ wide in order to take four pins at the chord intersections. At the web crosses two only are used. At all chord intersections and some in the web a ¾ bolt is used to hold the plank firmly together. This bolt is deemed of great importance from its preventing the plank from opening, which would greatly increase the

leverage on the pins. It is possible that iron pins perhaps of heavy pipe rather than solid bars would mark an advance over the present practice, but they have not yet been tried so far as the writer is aware.

The floor beams in these bridges are at present invariably hung below the chord, two beams per panel. The ends of the web plank projecting below the chord are cut into to allow space for each floor beam. They are hung by bolts passing through the open spaces in the chord and through washer blocks on top of same.

The lateral bracing is the Howe system, that for the lower chord being laid directly on top of the floor beams, and the stringers cut over it; 5″ by 8″ to 12″ is the size generally used. The main stringers under the rail are 10″ by 10″ and the side stringers 6″ by 10″.

The load used for floor beams is 5,500 pounds per lineal foot of track, which is assumed to cover both the live and dead loads. Eighty per cent. of this is assumed to be on the main stringers and 20 per cent. on the side ones. The clear width in these bridges is 15 feet. This makes the effective length of floor beams 18 feet or more and calls for sticks so large that it is best to use Southern pine for them. Spruce can be readily obtained of sufficient size, but when so large and in so exposed a situation it twists and checks badly. Southern pine is used also for bottom chord plank for spans greater than 100 feet, and should always be used for bolsters and wall plates. The stone parapets of all through wooden bridges are brought in so as to be flush with the face of the abutment (see inset). This serves to protect the timber floor from the weather, obviates the large amount of blocking needed on the stonework when it is not so done, and shortens the bridge floor.

Lattice bridges are built on the Boston & Maine Railroad as above described up to 150 feet clear span. They are, however, rather unwieldy at this length and it is preferred for spans above 125 feet to build them with an arch inserted between the webs. These arches are built up to the required section with 2″ or 3″ plank and bolted to the trusses at every lattice cross which comes in contact with the arch. They abut against the stonework below the lower chord on large Southern pine skew-backs scribed to the stone. The skew-backs are mortised out in steps to receive the square ends of the planks. The planks of the arches are well spiked when laid and radial bolts are freely used to bind them well together. The load is brought upon the arch by vertical rods passing through the arch and down through the lower chords and floor beams.

The arch is proportioned to carry its own weight and the whole live load on the bridge. The trusses are made of the same section as those of one half the span which have no arch. These compound bridges are very satisfactory, being rigid under traffic and of more pleasing appearance than when built without arches. They are also much more econo-

mical of timber than simple trusses for the reason that the arch uses timber wholly in compression, in which condition the entire section is available; whereas when timber is called upon to act in tension a large portion of the section must be wasted in making the connection.

In order to secure a satisfactory track surface after several years' use, there must be considerable camber framed into lattice bridges. For trusses without arches, there should be 1″ for each 25′ of span and for those with arches 1″ for about 37½′ of span.

The lattice bridge has been described thus at length, partly because it has not been so fully treated as other styles in technical literature, and because it is the only kind that can be built in competition with iron at present prices. On the Boston & Maine system, there are many Howe and Pratt bridges, a few Burr, Briggs and Child's trusses and many of mongrel type; but the Town lattice has a large plurality over any other kind and there seems to be ample and good reasons for its natural survival.

These bridges as built to-day are, in all their important details, direct descendants of, and very near kin to, those built in years past by the bridge carpenters of Northern and Central New England. Those built by David Hazelton and his men furnish the basis of the present practice on this road and although they were built without engineering advice, they bear analysis well, with the possible exception of the bottom chords.

It has come within the observation of the writer many times that when an intelligent master-carpenter has had the care for a term of years of a line of wooden bridges covering any given style of truss, he gradually brings their parts, when building new ones, to almost the exact size called for by scientific analysis when actual loads are used in calculation. He will use iron rods that are too small for they show him no distress unless they break, but the timber parts guide him to right results.

It is this property of a timber bridge, its certainty of giving warning of approaching weakness, that has kept the record of wooden truss bridges so clear from fatal disasters. It is not reasonably safe to use a light iron bridge until it is worn out, but a wooden one may be used till its deterioration is rapidly approaching the end. Neither is it safe to entrust light iron bridges wholly to the care of workmen not technically educated; the timber parts of wooden ones may be.

It is no part of the intention of this paper to advocate building wooden bridges instead of properly designed iron ones, but rather to describe the favorite styles now used on those parts of the Boston & Maine Railroad where wooden bridges prevail, and to show that these styles are not so obsolete as seems to be supposed in some quarters.

DISCUSSION.

MR. B. W. GUPPY.—The Town lattice truss was patented in 1820 or 1821. The inventor, Mr. Ithiel Town, published pamphlets in 1821 and 1831, describing the bridge, and the claims that he makes therein as to the economy and durability of this type of bridge have been fully substantiated. Copies of these pamphlets are in the possession of the Boston Public Library.

Some of the advantages that Mr. Town claimed for his bridge are as follows:

"Suitable timber can be easily procured and sawed at common mills, as it requires no large or long timber.

"Defects in timber may be discovered and wet and dry rot prevented much more easily than could be in large timber.

"There is no iron-work required, which at best is not safe, especially in frosty weather."

This last statement is rather amusing, as Mr. Town previously states that the trusses can be built either of wood or iron. Moreover, it is due to a free use of iron that the present development of the bridge has been obtained.

Iron is used principally in the form of bolts and rods, and its use increases the strength of certain parts like the tension chord, and allows of adjustments to take up the shrinkage of the timber.

Wedges at the ends of the pins or treenails were used to keep the sticks in close contact. Bolts at the intersections of chords and lattice are now used for the same purpose, and they also add to the strength of the chord connections.

Iron chord couplings add a large percentage to the strength of the tension chord.

A Howe truss system of lateral bracing is used instead of the Burr system originally adopted, and by means of turnbuckles on the rods placed so as to be easy of access, adjustments can be made to keep the trusses properly in line.

Formerly the floor beams in through bridges rested on top of the bottom chord, bringing most of the load on the inside chord sticks and web system. The present practice is to hang the floor beams below the bottom chord by hanger bolts alternately on opposite sides of the chord, as shown on the drawing accompanying Mr. Snow's paper. This distributes the load equally between the two web systems and adds an amount to the headroom equal to the depth of the chord plus the depth of the floor beam.

Some of these bridges have a very long life. One that was taken down on the Boston and Maine system last year and replaced by a simi-

lar structure was claimed to be over fifty years old, although no exact record could be found. This refers to the trusses. The floor was newer, having been renewed and strengthened. The timber was in fairly good condition, extreme lightness of construction being the principal cause for renewal.

Another bridge taken down the year before was over forty-five years old.

In use these bridges stand a great deal of abuse. A butting collision on the approach to one bridge piled the cars of one train up through the roof. Beyond breaking a hole in the roof, and cutting up a few ties, no damage was done to the bridge. Another collision in which only one train participated, the bridge acting as a buffer, resulted in considerable damage to the end vertical and web; but the bridge is still in use without any repairs and is considered to be perfectly safe. In another case logs at high water broke off the ends of the lattice. Bolts were put in connecting the floor beams with the upper lower chord, relieving the lower joints of all vertical load, and as they are still strong enough to transmit the chord stress, the bridge is used without any apprehension of danger. This bridge has the floor beams resting on top of the bottom chord. If they had been hung below they would have protected the ends of the lattice.

During the recent floods in New Hampshire, a pier was washed out from under a two-span bridge. As the invariable practice is to make these bridges continuous over all intermediate supports, the bridge was saved.

At the same time the abutment was washed out under the end of another bridge, causing one of the trusses to settle several feet. It was blocked up into place and is now in use, the flexibility of the construction preventing any serious damage.

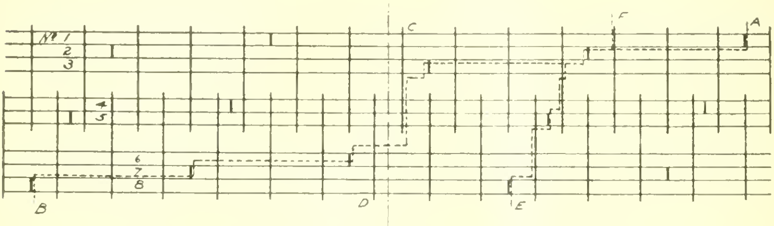
Fire is the principal enemy of these bridges, but the danger has become much less since the introduction of coal burning engines. The fires usually start in the roof and are generally extinguished before they do any damage to the trusses. A good coat of white-wash together with water barrels, buckets and a ladder at each bridge are the means of protection.

The road has these bridges insured, but as fatal fires are so few, and the losses are generally so small, it would seem to be economy to have the road do its own insuring.

In designing this truss, the practice is to use a panel length of from four feet to four feet six inches, the panel length being the distance between the chord pinnings for one of the lattice systems. The pinnings of the second lattice system are half way between those of the first. This brings the distance between two pinnings equal to one half a panel

length. The panel length is taken at such a length within the limits given as will bring the total number of panels equal to $n + \frac{1}{2}$ where n is any integer. This arrangement brings the center line of truss halfway between two pinnings, making the chord stick cuts symmetrical, and making the odd length sticks the same at both ends.

The method of arranging the cuts in an eight-chord stick is shown in the accompanying diagram.



In figuring the strength of the tension chord, the following assumptions are made:

(1) When there are four pins and one bolt at a pinning, the net area of the stick is taken as the depth in inches minus five, multiplied by the width.

(2) The value of a pinning to transmit stress between two sticks is taken as 1,100 pounds for each pin and 600 pounds for one bolt, making a total of 5,000 pounds for one pinning of four pins and one bolt.

These values were arrived at by figuring the pin for bearing, shearing and bending; the limiting value being given by the strength of the pin to resist bending. The lever arm was taken a constant of 1.3 inches for the three thicknesses of plank generally used, namely $2\frac{7}{8}$, $3\frac{3}{8}$, $3\frac{7}{8}$, as the flexibility of the pin must cause the load to be concentrated near the inner edge of the stick and the examination of pins taken from old bridges seems to justify this assumption.

When wrought iron chord couplings are used, the strength of a coupling is the net value of four $\frac{7}{8}$-inch rods at 10,000 pounds per square inch, or 16,920 pounds.

When chord couplings are used, there are two cases to consider: (1) when the strength of one coupling plus three pinnings is less than the net strength of the stick, and (2), when it is greater.

In the second case, the weakest center section is practically straight across the chord on the line $C D$. In the first case, the minimum value of chord is along the line $A B$. There is also a section $E F$, $1\frac{3}{4}$ panels from the center, the strength of which should be investigated, as in some cases it has a less value than the center section.

In the bridge shown in the drawing, the bottom chord is composed

of six 14 x $3\frac{7}{8}$-inch sticks and two 14-inch x $2\frac{7}{8}$ sticks. Net value of one 14 x $3\frac{7}{8}$ = 9 x $3\frac{7}{8}$ x 1000 = 34,875 pounds.

One coupling = 16,920 pounds,
Three pinnings = 15,000 "

31,920 " which is less than net stick and the minimum center section will be along the line *A B*.

Stick 1	1 coupling	3 pinnings	31,920
" 2	1 "	3 "	31,920
" 3	1 "		16,920
" 4	net stick	14 x $2\frac{7}{8}$	25,875
" 5	"	"	25,875
" 6	1 coupling	1 pinning	21,920
" 7	1 "	3 pinnings	31,920
" 8	1 "	3 "	31,920
			218,270 lbs. net value of center section.

Section $1\frac{3}{4}$ panels from center

Stick 1	1 coupling	3 pinnings	31,920
" 2	1 "	1 pinning	21,920
" 3	net stick	14 x $3\frac{7}{8}$	34,875
" 4	"	14 x $2\frac{7}{8}$	25,875
" 5	1 pinning		5,000
" 6	net stick		34,875
" 7	net stick		34,875
" 8	1 coupling		16,920
			206,260 lbs. net strength of chord $1\frac{3}{4}$ panels from center.

With sticks 16 inches deep and the same widths the center section will have a value of 229,770 pounds, and the other section 235,260 pounds, being the greater in this case. Inspection shows that the strength of the center section is increased only by the increase in sticks 4 and 5.

This span is about the limit of this style of bridge without the use of an arch, although spans have been built up to 150 feet.

THE ENGINEERING HISTORY OF A LAW SUIT RESPECTING A CONTRACT FOR RAILROAD BUILDING IN SOUTH DAKOTA.

Read before the Boston Society of Civil Engineers, June 12, 1895.

By Francis C. Tucker, Member of the Society.

On April 7, 1890, a written contract was entered into for the construction (not including bridges and track) of 103 miles of the Grand Island & Wyoming Central Railroad, extending from the Cheyenne River, near Edgemont, to Kirk, near Deadwood,—through the heart of the Black Hills of South Dakota. May 15, 1890, ten miles of this (not consecutive) were sub-let by oral contract to a firm of sub-contractors, and August 21st following, this contract was reduced to writing, the sub-contractors obligating themselves to fully complete the railroad (excepting bridges and track) on or before October 30, 1890. Grading began May 24, 1890, but was not entirely finished until about January 24, 1891—nearly three months later than the limit of time named in the contract. About one month after completion of grading the final estimates were sent, duly checked and certified by the Resident Engineer, to the Chief Engineer, who, having satisfied himself as to their accuracy, duly rendered to the principal contractors a statement of the same final quantities, and they in turn sent a statement of them to the sub-contractors.

Approximate monthly estimates were made regularly during the progress of the work. The sub-contractors were dissatisfied with these, and had their work remeasured and re-classified immediately on completion by F. S. Mitchell, of St. Louis, and J. E. Thomes, of Kansas City. These engineers had a profile of the work, but not the cross-section notes. The total quantities of earthwork returned by them were 10,888 cubic yards less than the Company's engineer certified to—a difference of less than 3 per cent. Their classification being somewhat higher than that of the Company's engineers, rather more than made up in value the shortage in quantities.

March 23, 1891, the sub-contractors filed a lien, entirely ignoring the quantities and classification of their engineers, Mitchell and Thomes. They used, approximately, the quantities of the final estimates given by the Company's engineers, but they slightly increased them in places. The classification claimed in the lien, although not entirely different from that of the Company's engineers, was, however, founded apparently on no actual measurement, but was made up by arbitrarily transferring large

quantities from earth to loose and solid rock, just as whoever made it up deemed advisable.

Apparently to support these small changes of quantities and large changes of classification, the sub-contractors had their work again measured and classified in September, 1891, by an engineer with three assistants. The pay yards he returned were 42,370 in excess of the final estimates of the Company's engineers—nearly 12 per cent. greater. The lien was assigned to an outside party and suit brought in the United States Circuit Court, District of South Dakota.

At sub-contract prices the value of the work done, by final estimate, amounted to	$87,380 34
The lien claimed a value of	118,350 96
Sub-contractors' engineer claimed a value of	128,184 32
Showing an extreme difference in value of	40,803 98
In addition, the lien claimed for delayed right of way, and consequent work after frost	29,936 22
For changes of section bounds, line and grade	14,658 40
For miscellaneous extra work	4,164 00
Making the gross difference of values	$89,562 60

From the amount directly involved, and the value attached to this case as a precedent, it has attracted much attention. "The taking of the evidence alone required two months' time, and when transcribed, filled 4,000 typewritten pages, besides which there were between 300 and 400 exhibits introduced and made part of the testimony. All of this vast volume of evidence was finally referred to Judge Bennett by order of Judge Edgerton. The hearing before Judge Bennett was most extensive, the arguments alone taking thirteen and a-half days' time. Messrs. Martin & Mason, Schrader & Lewis, and Mr. C. M. Brown appeared for plaintiffs, Messrs. Marquett and Griggs for the Railroad Company, and Mr. Frawley for the chief contractor. After Judge Bennett had carefully considered the case and had gone over the work in question, personally, in order to satisfy himself as to what the facts really were, he made an exhaustive report, sustaining fully the estimates of the Company's engineers, finding upon all points at issue in favor of the defendants. To this report the plaintiffs filed numerous exceptions, which were argued before Judge Dundy by Mr. Martin and Messrs. Griggs and Frawley. In addition to the oral arguments, briefs were filed by the attorneys and the case most carefully presented to the Court. Judge Dundy rendered a decision upon these exceptions in which he fully sustained the determination of Judge Bennett.

"There were many nice and intricate legal questions involved in this suit, turning upon engineering practices, all of which were

decided in favor of the methods and determinations of the 'Burlington' engineers."

From this brief history of a suit, that it has taken four years to determine, we turn to those parts of the decision that are of special interest to civil engineers.

QUANTITIES AND CLASSIFICATION.

The pay yards of earthwork were returned as follows:

	Earth.	*L. Rock.*	*S. Rock.*	*Totals.*
By Company's engineers . . .	223,954	77,987	51,393	363,334
By lien	116,211	188,483	63,395	368,089
By sub-contractors' engineer .	127,822	212,330	65,552	405,704

A careful inspection of these figures shows a more extraordinary difference in classification than the 42,370 cubic yards difference in total pay yards. Judge Bennett, the Master in Chancery, says in his report to the Court: "The measurement and classification by the sub-contractors' engineer are not entitled to any weight in the consideration of this cause for the following reasons:

"(1) In the measurement of cuts he included practically all the quantities found by him to have been removed, notwithstanding that (1) the contracts required that the quantities to be paid for should be ascertained from the cross-section notes of excavation and embankment prisms, and that only such quantities should be computed as were found within the slope, grade and surface planes; (2) by this method he disregarded the provision of the contracts by including large quantities of material not within the slope, grade and surface planes, thus greatly increasing the quantities above what they should have been; and (3) his measurements included, as having been done by the sub-contractors, a large quantity of material which had not been removed by them, but had been taken out by the Railroad Company after the sub-contractors left the work.

"(2) He determined the quantity of borrow by measuring the pits from which it had been taken, wholly disregarding the provision of the contracts requiring that all borrow should be measured in embankment, and greatly increasing the quantity over what it should have been.

"(3) In his classification he was not governed by the contracts under which the work was done. On the contrary he classified material which had been removed from the channels by plowing with six horses or mules, or less, as loose rock, for the alleged reason that channel excavation was more difficult to handle than like material found elsewhere.

"Again, he was governed in classifying alone by geological consid-

erations; or, in other words, by the appearance of the material adjoining that which had been removed, and wholly ignored the provision of the contract requiring that material should be classified according as it could be removed—for instance, that earth should include all material which could be plowed with a good plow, drawn by six good horses or mules, etc., and should include everything not distinctly loose or solid rock."

Another reason for large differences in quantities was that the engineers of the Railroad Company substantially gave the true prismoidal quantities, while the quantities given by the sub-contractors' engineer were obtained by averaging end areas without correcting in any way for the most extreme differences in consecutive cross-sections, although he took his cross-sections much further apart, usually, than the Company's engineers did, thereby much increasing the need of correction. He carried the method of averaging end areas to the extreme of using it at both ends of every cut on side-hill; that is, he invariably treated material which was actually pyramidal in form as being wedged-shape, thereby increasing the quantity by fifty per cent. An attempt was made in the evidence to show that custom had established the method of averaging end areas without correction; in effect, legalizing it. To disprove this the defendants introduced in evidence the following portions of standard works:

Computation from Diagrams of Railway Earthwork, Wellington. Preface, page 4.

"Economic Theory of Location of Railways, Wellington." Page 896, articles 1257 and 1258.

"Field Engineering," Searles. Page 203, article 235; page 225, article 254; page 229, article 256; page 236, article 263; page 200, article 231; page 201, article 232.

"Excavations and Embankments," Trautwine.

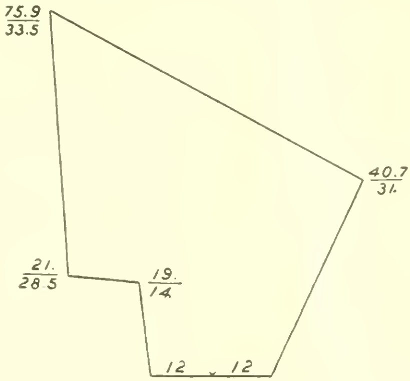
"Engineer's Pocket-Book;" twenty-fifth thousand; p. 161, Trautwine.

"Mensuration of Volumes." Page 129, Davies' Legendre.

They also claimed a strict interpretation of the contract, which says: "Payment being made only for number of yards actually removed by contractor, within the specified slope, grade and surface planes," and "Earthwork will be computed from cross-section notes of excavation prisms; that is, the quantities between the slope, grade and surface planes shall be taken, and shall be paid for by the cubic yard of twenty-seven (27) cubic feet."

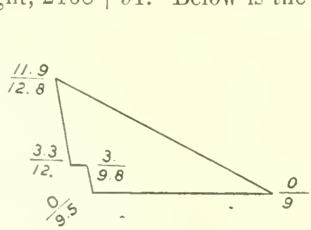
To show the importance of this question of methods, and the extortion that an unscrupulous engineer might perpetrate by a judicious misuse of the averaging end area method without correction, several test cases were selected from the cross-sections as measured and used by the

sub-contractors' engineer, models were made and put in evidence, and the differences between the two methods of computation amply testified to. In one instance that engineer added, according to his own measurements, in a prismoid only 32 feet long, 439 cubic yards of excess, and this in solid rock. Below is his cross-section at station, 2168+64.



STATION 2168+64.

His next note is "Grade at 2168+96," and he estimated the excavation between these two cross-sections, 32 feet apart, by simply averaging end areas. If any reader doubts the absurdity of using the average end area method without correction, in figuring quantities between such highly different cross-sections, he is advised to figure correctly and compare results. As this work was on steep side-hill the solid between these two plusses was not a true prismoid, and to figure the true quantity from the above notes it was necessary to interpolate a section at the grade point on the right, 2168+91. Below is the resulting cross-section at that plus.



STATION 2168+91.

The sub-contractors' engineer estimated between

2168+64 and 2168+96	1,672.4	cubic yards.
Correct prismoidal quantity	1,233.7	"
Error of method in 32 feet length	438.7	"

This is an extreme case, and simply emphasizes the necessity of correcting, in such cases, the results obtained by averaging end areas. In

this connection it is proper to call attention to, and heartily endorse, Mr. Wellington's Article 1258 of his "Economic Theory of Location of Railways": "The proper method of computing earthwork in construction is to compute by end areas only, and then at any later time, when convenience serves, to determine the prismoidal correction for those solids only which need it, which are those differing by more than two or three feet in center-height. These corrections are then added together for each cut or section and deducted in gross from the end area volume. The reasons which make this method at once the simplest and the most accurate of all, and the evidence from experience that it is so, are given at length in the writer's treatise on the computation of earthwork."

A further reason for the excessive pay yards estimated by the contractors' engineers is their complete ignorance of the natural surface of cuts, channels and borrow pits, necessarily removed in construction before they went upon the ground; in one place they counting the surface fully 25 feet above what it had actually been. By the contract they should have found the amount of the borrow by measuring the banks and deducting from their amount the total available material from cuts, channels, etc.; instead of so doing they attempted to measure the borrow pits, assuming the surface to have been straight from side to side in spite of the fact that many of the pits were over 100 feet wide and were in the edge of the valley, where the hill joined the bottom, and were thus almost necessarily concave on top, containing very much less than the quantity computed. The evidence was conclusive that in certain places the banks contain thousands of yards less than the contractors' engineers found in the cuts and borrow pits. So much for ignorance of the natural surface.

Classification, under the contract, depended upon how it was practical to work the materials encountered; and was a matter of demonstration to the engineers who were upon the work throughout construction; but to those going upon the work after completing it was, necessarily, merely a matter of opinion; proof could then go no further than to attempt to classify what had been moved by inference from what had not been moved.

Portions of the line for which it was necessary to borrow were in narrow valleys where earth was rather scarce, but the contract required the contractors to borrow earth at the price of earth excavation, if to be found within the limit of haul—which was 1,500 feet. Free haul was 500 feet. In a few places loose rock, and even solid rock, was borrowed in spite of the protests of the engineers, and although earth was in every instance pointed out, and the attention of the sub-contractors and the foreman was called to the provision of the contract; the sub-contractors and foreman explaining that they were short of teams to haul the earth,

and that it was cheaper for them to put the loose rock in with wheelbarrows and men on account of the much shorter haul. Counsel for plaintiffs claimed that the engineers should have peremptorily demanded the hauling of earth—if it were there—and, if their orders were not obeyed, should have enforced their demands by requiring the discharge of all foremen not acceding to them. Counsel also claimed that since rock was thus taken it must be paid for, and that, since the Company's engineers had made no measurement or classification of borrow pits, and the sub-contractors' engineers' had, the classification of the latter was the only classification before the Court, and must be taken. This claim, like all others, was set aside.

The sub-contractors' engineers measurements exceeded those of the Company's engineers about as follows: In cuts, 24,533 cubic yards; in channels, 3,500 cubic yards; in borrow, 14,337 cubic yards. The excess in cuts came from the causes already named and from numerous errors, which, by a strange fatality, seemed to always be on the sub-contractors' side. Ignorance of the natural surface was a large factor here, as in borrow; cuts were figured over a hundred feet longer than they really were, many were figured wider; nearly all material removed up to September, 1891, was estimated, although fully 20,000 cubic yards had been removed by the railroad employees after the sub-contractors left the work.

The difference of 3,500 cubic yards in channels is fully accounted for by (1) including, in at least two places, natural channel which never was excavated by sub-contractors; (2) ignorance of natural surface; (3) the natural wash of seven months, including spring freshets.

The difference of 14,337 cubic yards in borrow came slightly from error and from methods of figuring, and from waste in hauling and shrinkage (which, by the contracts, were chargeable to the sub-contractor), but principally from ignorance of the natural surface before alluded to.

At sub-contractors' prices the total values of earthwork were:

By Company's engineers' final estimate quantities	$ 82,536 49
By lien quantities	110,534 86
By contractors' engineers' estimate quantities	120,368 22
Showing a range in values of	37,831 73

The Master and the Court decided, however, the Railroad Company's engineers' estimate to be in accordance with the contracts and the evidence.

MINOR CLAIMS UNDER THE CONTRACT.

In PAY HAUL the engineers develop no difference of estimate.

In RIPRAP the Company's engineers' estimate was for 592.6 cubic

yards at $1.25, and the lien claimed 1,299 cubic yards at $2.00. As to the price, all the other riprap on the line was sub-let at $1.25, but through an oversight the item was not named in this particular sub-contract. The difference in quantity arose from over estimate of thickness, some of it (from coarseness of material) having been built thicker than ordered, and from including as riprap mere rock slope, which the Company's engineers claimed the right to have built, within haul of clear rock cuts, by simply dumping the coarsest of the rock in cart-loads, as it came from the cut, on the side of the bank toward the stream, under a clause in the specification: "Where there is choice of material, the best shall be used on top of the embankment, for at least one foot in depth, *or as directed* by the engineer." In the award there is a slight error in figuring, but the Master seems to have adopted the measurement of the Company engineers, but to have made his sole concession to the claims of the plaintiffs by figuring the price at $1.75 per cubic yard.

In CLEARING, the lien claimed 97.6 acres against 82.8 acres allowed. This relatively small difference arose from the difference in interpretation of the only clauses in the contract relating to clearing:—"Clearing will be paid for by the acre for ground necessarily cleared for grade and borrow pits;" and one other, which is a mere naming of price:—"Clearing, per acre" (when necessarily done). The Company's engineers held, where clearing was scattering and only a small portion of the ground was shaded, that, except for the portion actually cleared, clearing was not done, therefore could not have been *necessarily* done, and therefore was not to be paid for. Plaintiffs claimed that where any clearing was called for, it should have been estimated as solid. The Court adopted the interpretation of the Company's engineers.

In GRUBBING, the same difference in interpretation developed as in clearing. The only clauses relating to grubbing in the contract were:—"Grubbing will be paid for by the station where necessarily done. Grubbing sage-brush and grease wood will not be paid for, but the price paid per yard for grading shall include the cost of such work;" and, "Grubbing, per station" (where necessarily done). The engineers measured all grubbing along the line and along detached work (like channels, etc.), figuring, in fractions, the next larger tenth of a station. The lien claimed even a single stump as a whole station. Then, of course, an estimate of grubbing, after the completion of work, is, necessarily, a mere guess from the appearance of the surroundings. The difference in value of all those minor claims under the contract was $2,972.25, only.

EXTRA WORK.

The lien claimed for *delayed right of way*, etc., and consequent work in *frost*, an additional price of:

12 cents per cubic yard	on	16,351	cubic yards	earth	$1,962 12
30 " " "	"	47,122	"	earth and loose rock.	14,136 60
50 " " "	"	11,046	"	(partly solid) . . .	5,523 00
100 " " "	"	6,282	"	. . . .	6,282 00
125 " " "	"	1,626	"	. . . .	2,032 50
	"	82,427	"		$29,936 22

Included in this total is a claim for, perhaps, $5,000 for change of line, which neither the lien nor the evidence makes it possible to separate from the delayed right-of-way claims, but which is barred out by this clause in the contract: "The party of the first part reserves the right to change the line and grade from that shown on plans and profiles furnished, but will not be held for damages on account of such changes."

This line ran through a strictly mineral country; claims lay around loose in all directions, overlapping each other—some of them abandoned. It was impossible for an outsider to be sure of the legality of any title till it had fought its way through the courts. Often no sign of occupation showed until, after construction had begun, the owner (?) appeared with shot-gun or revolver, and a violent temper. Right-of-way agents were kept traveling back and forth in the endeavor to keep all claims settled as fast as they could be believed genuine. Occasional threats were made, and, in a few places, gangs of men were forbidden to work, but only one injunction was served, and no actual force was used to prevent work. The evidence shows that the injunction was in force only about four weeks.

The whole matter of delayed right of way and work in frost was thus summed up by the Master in Chancery (eliminating legal terms and repetitions): "The claim for extra compensation, on account of alleged *delay* caused by the alleged failure on part of the railroad company to obtain right of way, by reason of which complainants claim that a large amount of work had to be done after frost had set in, is not sustained by the evidence; the sub-contractors not having been delayed in their work by reason of any act or default on the part of the defendants, or either of them. On the contrary, the sub-contractors kept all of their forces employed, and were not compelled to turn off either workmen or teams on account of the want of such right of way. The sub-contractors were not prevented by injunctions or default of defendants from completing their work within the time stipulated in their contract. Moreover, they never made any claim for damages, or demand for extra compensation to the defendants herein, or either of them, in any manner whatever. Again, the sub-contractors, if delayed by want of right of way, were allowed a much longer time by the railroad company than the period of such delay, in which to complete their work, after the date when it should have been finished.

"The claim for extra compensation or allowance, on account of work alleged to have been done at Nahant, after frost had set in, is not sustained by the evidence, as said grounds were staked out by the Company's engineers in ample time for all of the work to have been done before frost set in.

"The claim for extra compensation or allowance, on account of certain berms and channels, alleged by complainants, to have been staked out by the Company's engineers, after frost set in, and which, therefore, had to be graded in frozen material, is not sustained by the evidence, the berms and channels having been staked out as soon as required by the sub-contractors, and some of them long prior to the setting in of frost."

The lien claimed for changes of section bounds, line and grade, these items:

30 cents per cubic yard for 32,307 cubic yards on account of changing trestle work to fill across gulch, and moving line between sections 77 and 78 from station 1829 to station 1830, increasing fill from 3,340 cubic yards to 35,647 cubic yards	$9,692 10
10 cents per cubic yard additional for 23,422 cubic yards on account of difference between placing in spoil bank and hauling into line bank	2,342 20
Increased cost of work made necessary by change of line from station 2170 to station 2182+50, 30 cents per cubic yard additional for 8,747 cubic yards; a portion of this was hauled past section end and a large portion was hauled past bridge opening at station 2188	2,624 10
Claimed for changes ordered by engineers	$14,658 40

Besides a claim, previously alluded to, for about $5,000 that cannot be separated from the claims for delayed right of way.

The claims for changes made by order of engineers were thus disposed of by the Master in Chancery: "The claim for extra compensation or allowance, on account of an alleged changing of the section ending, at the north end of section 77, is not sustained by the evidence for the reasons that the sub-contractors agreed in the written contract to do the work up to the point where the section was actually ended; and, even if the section ending was changed, the Company's engineers had the right to change it, and no injury was done the sub-contractors.

"The claim for extra compensation or allowance, above the award made by the company's engineers, on account of the change of the section ending between sections 83 and 84, is not sustained by the evidence, for the reasons that the contract, under which the sub-contractors did this work, permitted such change to be made by the Company's engineers, and such change of section ending, worked no injury to the sub-contractors."

In the lien were presented miscellaneous extra bills, which may be grouped thus:

1. Clearing out channel of creek opposite heavy rock cut	$956 00
2. Waiting for placing of culvert; 4 teams, fifteen days at $4	240 00
3. Widening cut slopes—partly on account errors of engineers	938 00
4. Putting rock filling in crib—730 cubic yards at $2.00	1,460 00
5. Removing old flume and slab pile	94 20
6. Rock in creek for road crossing	6 50
7. Building and removing bridges for hauling borrow, etc., ...	197 30
8. Clearing and grading roads	272 00
	$4,164 00

In his report to the Court the Master in Chancery thus disposes of these: "The engineer gave no orders in writing, or otherwise, to the sub-contractors requiring the latter to do any extra work for which they were not estimated and allowed in the final estimate."

Some particulars of this extra work may be of interest to engineers:

(1) Heavy blasting in rock cut threw large masses of rock into a creek channel, forcing the water from it over a public road. The contract provided that the contractors were to be held liable for all damage to premises through which the road ran, and that the Company might retain an amount sufficient to cover those damages.

(2) The evidence was conclusive that the culvert in question was in place nearly a month before the delay was alleged to have occurred.

(3) The evidence was positive that no errors in cut widths or slopes were made by engineers. During construction, slopes were flattened because less stable material was encountered than was expected. All excavations ordered, and all slides that seemed unavoidable because of natural seams, were paid for.

(4) To fill a crib (built by other parties) the sub-contractors were told to get rock wherever most convenient, and they were paid for the estimated amount of solid rock excavation that was required to fill the crib, since it seemed to the resident engineer that he could, under the contract, have staked out an excavation in solid rock and required the material dumped into the crib, and no good reason appeared for paying a greater price for the easier service required.

(5) Removal of saw-mill débris and an old flume were held sufficiently paid for by clearing—especially as much of the material was converted by the sub-contractors to their own use for wheel-planks and to build sheds.

(6) Rock in road crossing was merely loose rock borrow.

(7) Building and removing bridges that were for the contractors' convenience: it is doubtful if these should have been paid for by the Company. These were not paid for as extra bills, but were liberally

equated in value as "clearing." This practice of equating the value of something not covered by the contract in terms of some item in the contract seems very objectionable to most engineers, but was not disturbed by the Court.

(8) Clearing and grading roads were clearly covered by items in the contract, and were properly covered by the estimate.

The petition sets forth the cause of action thus: "That when the work was completed the Chief Engineer made a pretended final estimate showing the quantity and classification of the work done by the sub-contractors under the contract, which pretended estimate is wholly false, fraudulent and erroneous; and, although the sub-contractors actually performed the amounts of work and at the prices specified in the annexed claim and lien alleged, the Chief Engineer, by fraud, error and mistake in his final estimate, estimated the work done by the sub-contractors as follows:" (Setting forth, with a few clerical errors, the correct amount as stated in the final estimate by the engineer.) As to these charges the Master reported to the Court: "The engineers of the railroad company acted fairly and in good faith in all matters pertaining to the measuring, classification and estimating of the work done by the sub-contractors, and the measurements, classification and final award were justly and fairly made according to the best skill and ability of the engineers."

The Master also reported to the Court these conclusions: "A legal and valid estimate and award of all work and labor done and material furnished by the sub-contractors, under the contract, was duly made and rendered by the Chief Engineer of the Railroad Company, as required by the contracts hereinbefore mentioned, and said estimate and award was and is binding upon the sub-contractors and the complainants herein.

"The complainants are entitled to take nothing by this suit, and the defendants and each of them should go hence without day."

EFFECT OF THE DECISION.

For several years the practice has existed to an undesirable extent among engineers, especially in the West, of classifying work according to its cost—using some judgment, of course, with regard to its management. Plainly stated, the theory seems to have been that, if a piece of work was well managed, the final estimate should show a profit, and that if badly managed it should show a loss. The price and other items of the contract have played second fiddle in the harmony (?) of construction. This practice has even been urged in papers presented by engineers of reputation to engineering societies, and has resulted in debauching the contractors and engineers; has put a premium on low and hishonest bidding by encouraging the idea that the main thing was

to bid low enough to get the work anyhow—depending then upon the mercy and dishonesty of the engineers to make the profits all right; has put a premium on poor management by contractors, since the tendency was for the engineers to rely upon the force account to determine the classification, and thus pay a poor manager more for doing a given amount of work than a good manager for doing the same: and, by preventing their getting the work, has injured the honest contractors—who made fair bids, expecting measurement and classification according to the contract and specifications—more than it has injured any others.

Against this improper practice, and in favor of a strict construction of contracts and specifications, this fight has been sustained for five years. To make the position tenable the policy was carefully inculcated of making no presents, but of giving to the contractors the benefit of every reasonable doubt.

The engineers on this work were: I. S. P. Weeks, Chief; F. C. Tucker, Resident, and F. A. Jones, F. C. Noble and J. C. Beye, Division. As an expert on methods and classification V. G. Bogue was called, after suit was begun, and his vigorous endorsement did signal service.

In closing, apology is due the attorneys in the case for the freedom with which the "saids" and "aforesaids" have been dropped in quoting from the carefully prepared law papers.

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APPROXIMATE ANALYSIS OF THE USE OF COAL IN AN EDISON ELECTRIC STATION OF THE TYPE STANDARD, ABOUT 1890.

BY R. S. HALE, MEMBER OF THE BOSTON SOCIETY OF CIVIL ENGINEERS.

[Read before the Society, May 15, 1895.*]

THE system of electric supply from which the following results are derived is the Standard Edison system of a 3-wire underground network for low tension, direct current supplied by underground feeders from three stations, located in Boston, one on Head Place near the corner of Boylston and Tremont Streets, one on Hawkins Street near Bowdoin Square, and one on Atlantic Avenue, foot of Pearl Street.

These stations pump electricity into the electric mains exactly as pumping stations or gas works might supply water or gas, only since the incandescent lamps must be supplied at almost absolutely constant pressure an electric network requires more feeding points than a network of water mains, or gas mains.

The stations are as follows: The first station on Head Place has 18 units, each consisting of an Armington & Sims non-condensing engine, 15 x 15½ inches, belted directly to two Edison No. 20 B. P. dynamo. Each dynamo is rated at 400 amperes and 125 volts or 50 K. W., the engines at 135 H. P. The engines are supplied with steam at 95 pounds pressure from six return tubular boilers of 1,800 square feet of heating surface each, and five Babcock & Wilcox boilers of 3,220 square feet of

* Manuscript received August 7, 1895.—*Secretary, Ass'n of Eng. Socs.*

heating surface each. The second station on Hawkins Street has ten exactly similar units supplied with steam at 100 pounds pressure from two Heine boilers of 2,600 square feet heating surface, one Heine of 1,640 and two Babcock & Wilcox boilers of 2,795 square feet heating surface each. At the Atlantic Avenue or third station are four triple expansion marine type condensing engines of 650 H. P. each, direct connected to two 200 K. W. General Electric, M. P. dynamos. These engines are supplied with steam at 160 pounds from seven Babcock & Wilcox boilers of 3,737 square feet each. There is also a storage battery of 140 Tudor cells of 3,470 ampere hours capacity on each side of the 3-wire system.

The supply of electric current, which may be used for incandescent lamps, arc lamps and motors indifferently, and is supplied at 110 volts, or 220 volts between the outside wires of the 3-wire system, is best shown by our load curves. Here is a curve, Fig. 1, of a summer day beginning 7 A.M. The first part of the curve is the motor load and office lighting which drops off for lunch at noon and again at 5 P.M. The evening load is residence and shop lighting. In the spring and fall, represented by the curve in Fig. 2, day and night load merge into each other, and in the winter, Fig. 3, they overlap, giving us this peak.

The dotted curves below the full curve of total output are the curves of the districts normally supplied by the different stations. Now the third station is of higher first cost and also of much less operating cost than the other stations. You can readily see that it would not pay to pay interest on costly apparatus to supply this peak that lasts only a few hours a day a few months in the year, independently of the copper needed to transmit this maximum load to the other parts of the city, but yet at light loads it seemed a pity to have costly engines lying idle while cheap ones were eating up the coal pile. Large feeders or tie lines were therefore put in with the idea of carrying our average load during the great part of the time on the engines of good economy, using the Head Place and Hawkins Street stations only as reserve and to supply the peak of the winter curve. The result is that with less than 40 per cent. of our investment in high-priced economical machinery, we are able to carry over 90 per cent. of our average load on it. It is the same principle as putting in a good pumping engine for water service and a cheap one for reserve and for fire service, only it is a little harder to work out for electric supply.

Up to May, '93, we had no tie lines and ran the engines at each station to supply the normal load of the district. Since May, '93, we have been able to shut down the uneconomical stations a large portion of the time, bringing down their average load and bringing up that of the third station. The effect of the tie lines is shown by these curves, Fig. 4, which

give the load manufactured by the different stations and the total. The first three figures give the curves of distributed load. Unfortunately only the second station is available for the comparisons of the use of coal we are now about to make, since the first station supplies a great deal of steam heat of which no record can be made, while various causes in addition to the change of load have affected the third station. For the second station we have the following data by months: Tons New River coal. Tons wharf screenings. Average K. W. Engine hours. These are obtained as follows: At the first of the month coal on hand is measured, amounting to from 50 to 100 tons. All coal brought into the station is weighed on the carts and at the end of the month coal is again measured. Coal weighed + or — difference on hand, is coal used, and

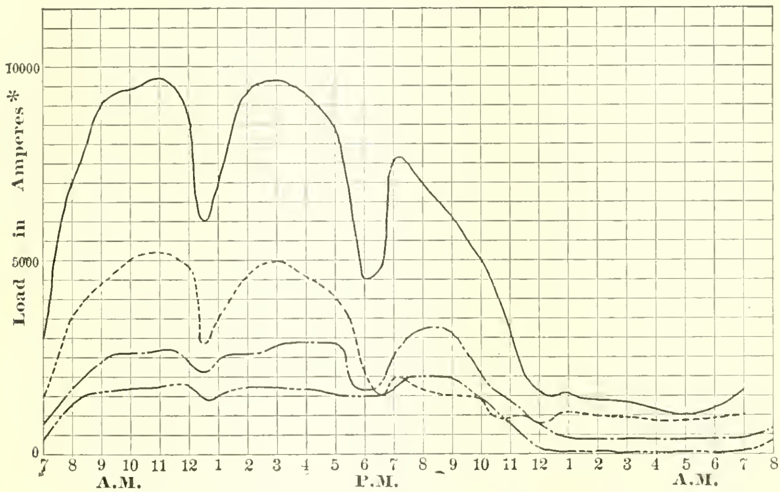


FIG. 1.—LOAD DIAGRAM, AUGUST 21. WEATHER FAIR.

is divided between New River and screenings in proper proportion. Half-hourly records are kept of the amperes and volts, which give the K. W. hours, and hourly record is kept of the number of engines running. We then get the derived figures of pounds coal per hour and per K. W. hour and average K. W. per engine. (See table.) These *figures* only show a much worse economy at small average loads, but drawing with average K. W. as abscissæ, two curves, Fig. 5, of pounds coal per hour and pounds coal per K. W. hour we find fairly regular curves, showing that there is a law connecting them. Examining the right hand side of the first curve we find a straight line whose equation is

$Y = a + b\,x$. Where $Y =$ pounds coal burnt per hour $x =$ aver-

* At a pressure of 110 volts at feeder ends.

age K. W. a and b constants which work out to $a = 500$ pounds, $b = 7\frac{1}{2}$ pounds.

These are obtained using only the right hand portion of the straight line curve, which represents times when the station was ready to turn out its full load or nearly so. The left hand portion is when some of the boilers and some of the steam piping is shut down, making in fact a smaller station, which accounts for the droop. In our equation we will first put the load, or $x = 0$. Then $y = 500$ pounds per hour, which is what is necessary to keep the station ready for full load without turning out any load. The other constant is evidently the pounds per

Fig. 2.—Load Diagram, October 1. Weather Cloudy.

K. W. hour of any additional load after paying the 500 pounds per hour to keep the station ready. Seven and a half pounds of this coal per K. W. hour is equivalent to about 50 pounds steam per E. H. P., or near to 40 pounds per 1 H. P. hour, and since the engines are necessarily run a large part of the time either under- or overloaded, this does not compare unfavorably with the figures obtained for this class of engines on test runs.

It should be noted that there are enough engines so that the over- and under-loading of the engines is not markedly different for different

* At a pressure of 110 volts at feeder ends.

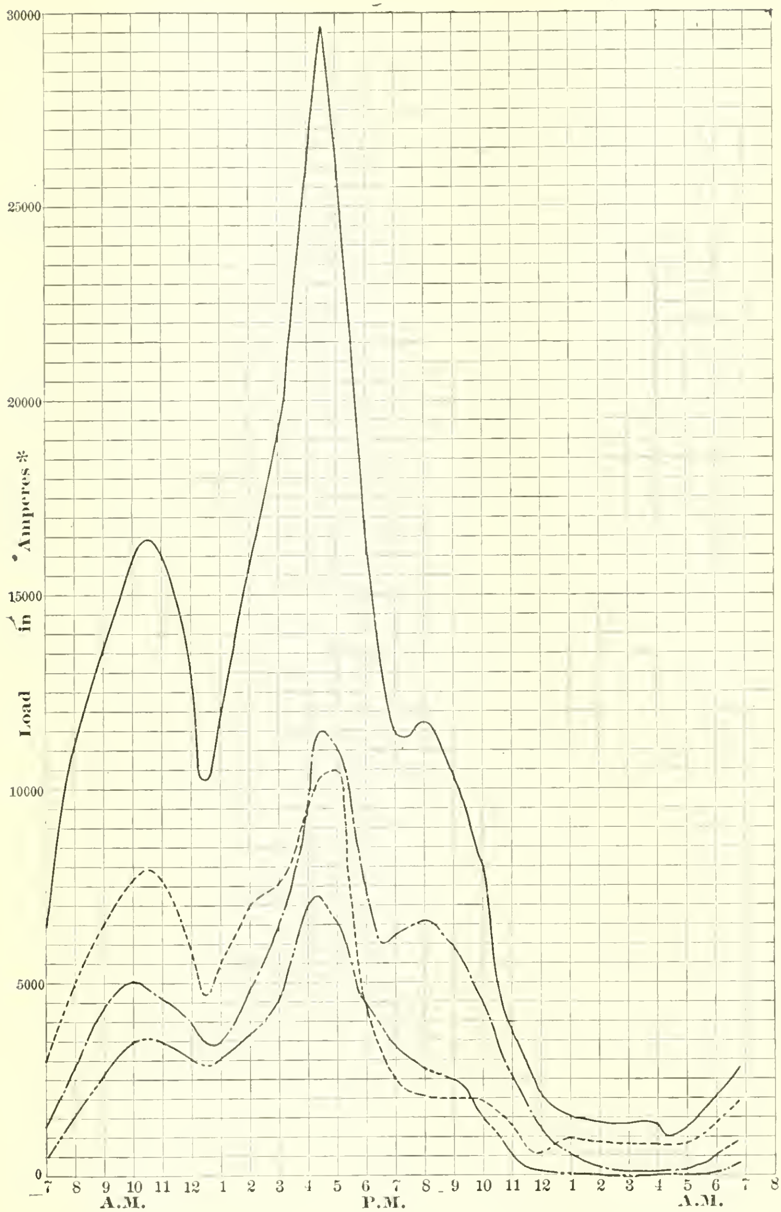


Fig. 3.—Load Diagram, December 12. Weather Cloudy.

* At a pressure of 110 volts at feeder ends.

average loads on the station as is shown in column of average K. W. per engine in the table.

This constant loss of 500 pounds per hour is composed of boiler losses, which are hot chimney gases, and radiation from boilers, and steam pipe losses, including radiation from steam pipes and steam leaks. The two latter were determined as follows:—

All drips were returned by a Gassett trap to a large tank half filled with cold water. The size of the tank being known the increase in depth gave a measure of the condensation. All the engines were shut down, hence the total water used as per meter during the test or seven hours corrected for height of water in boilers and minus the water condensed, was a measure of the steam or water leaks. The result was surprising, the leaks amounting to about 500 to 600 pounds water of steam per hour, the condensation to only about half that amount on a warm winter night. Another test on a very cold night gave about 800 pounds leak per hour, a condensation in only a part of the piping was about 400 pounds. Still another test, with one half of the steam piping and all but two boilers shut down, gave radiation 200, leak 600, on a moderately cold night. A test one moderately warm day gave 500 pounds leak per hour. The condensation includes the heating of the second story of the building. The daily figures for water consumption at light loads after allowing an estimate for use for water closets, etc., and for actual steam in engines themselves, bear out these figures. As these figures for leak seem very large, I wish to say that at our third station the tests show still larger loss than at the station under discussion, yet at least one member of this society has twice complimented me on the excellent job of steam piping there. Besides, 600 pounds per hour for even 20 hours is only about 200 cubic feet, and when boilers are left low at end of run and then pumped full to be ready for the next run, such a quantity may easily pass unnoticed. The contraction of water when cooling and the curious vagaries of the water in the water glass of a banked boiler would also help the leak to escape detection, without special tests.* Six hundred pounds steam leak is about 66 pounds coal per hour. Say 300 pounds steam condensation is about 33 pounds coal per hour. Subtracting these from the total of 500 pounds, leave as the boiler losses about 400 pounds coal per hour for say for 4½ boilers on an average.

Separate tests indicate that it takes about ¾ ton coal per day to keep up the pressure in a boiler of 250 to 300 H. P., without making any steam, which, allowing for somewhat greater loss at full load, checks up the figure of 400 pounds we have just obtained as well as we can expect in any discussion of this sort.

* See also *London Engineering*, April 5, 1895, for the amount of this loss in steamship practice.

Fig. 4.—Load Diagram, December 13. Weather Fair.

It seems probable that the boiler losses may be chiefly in the chimney and not in direct radiation when we remember how long a boiler will keep up its pressure with the fire drawn, provided the damper is tightly closed, but some boiler trials I have made render me very chary of forming a definite opinion on this subject. We then have for this

* At a pressure of 110 volts at feeder ends.

station of 1000 K. W. capacity, 1350 rated I. H. P., 12,390 square feet boiler heating surface.

66 pounds coal per hour . . steam leaks.
33 " " " " . . radiation from steam pipes.
400 " " " " . . hot gases and radiation from boilers.

Total 500 " " " " . . constant loss independent of load.

Power produced 7½ pounds per K. W. hour in addition to constant loss.

It need hardly be said that these figures should not be considered as an exact analysis, but merely as giving an idea of the relative value of the quantities. Nor are they presented on account of their excellence, though there are many reasons in the nature of our business why we cannot ever get as good results as with the absolutely constant load of a pump, or nearly so of a mill, but I hope they will be of interest as showing some results of actual running. I may add that we are to-day producing power at our new station at a cost per unit less than half of what it formerly cost us in our present sub-stations.

	Tons N. R. Coal	Tons Dust	Eng. Hours	Ave. K. W.	Lbs. Coal per hour	Lbs. Coal K. W. hour	Ave. K. W. per Eng.
1893.							
January	421	333	2432	211.7	2032	9.57	64.7
February	386	292	2102	198.2	2080	10.16	63·5
March	417	338	2423	204.7	2036	9.92	62.8
April	256	256	1633	124.9	1424	11.4	61.2
May	147	163	612	46.8	836	17.8	56.8
June	79	99	114	7.8	496	61.5	50.8
July	54	54	7	.3	292		50.4
August	42	58	30	1.2	270		30.9
September	67	83	98	7.2	418	58.0	52.2
October	92	116	352	17.7	562	31.7	52.9
November	87	97	375	25.2	512	21.3	48.4
December	118	134	384	22.5	680	29.9	43.9
1894.							
January	104	105	596	37.9	748	19.6	47.4
February	98	111	415	30.9	622	20.2	50.0
March	92	109	299	20.9	542	25.9	52.1
April	60	69	184	14.4	258	25.0	56.4
May	7	9	0	0			
September	6	3	0	0			
October	29	29	87	7.0	156	22.3	52.9
November	86	91	256	21.8	492	22.7	61.4
December	150	155	412	41.1	822	20.0	74.1

By the kindness of the President of one of the Edison Illuminating Companies I am enabled to add as an appendix the following extracts from one of his reports. His station is very similar to the one we have been discussing, except that it is two or three times the size, and has some compound engines:

"Calling your attention to the fact that the operation of this station

is for the purpose of earning money, I would particularly call the attention of the Board to the excess of the relative consumption of coal on Sundays over week-days, as compared with the load. You are all aware that on Sundays the amount of coal burned per H. P. hour sold usually more than doubles the amount of coal burned on week-days; and for this reason our Sunday load is very unprofitable. This discrepancy, however, points out to us the existence of a very large constant waste, and by means of the proper comparison it enables us to determine the amount of this waste:

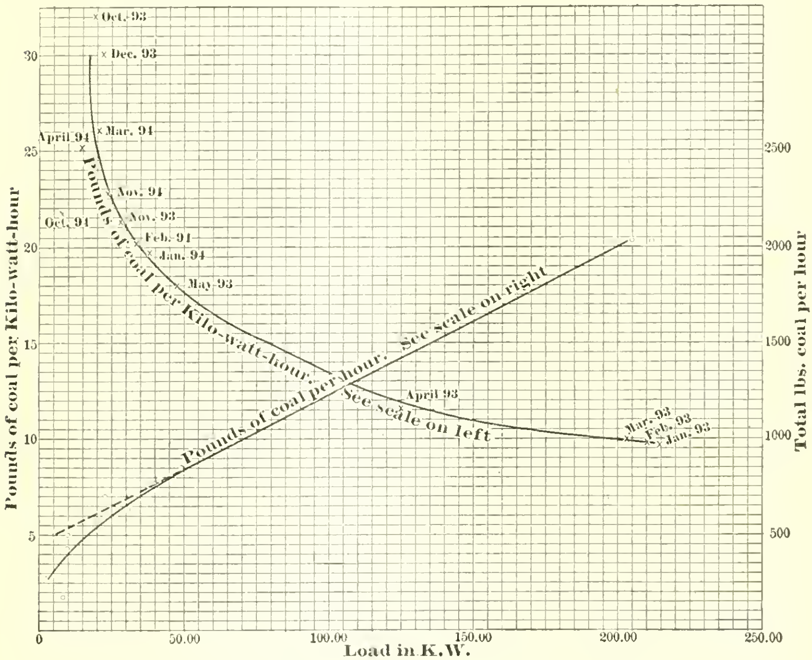


Fig. 5.—Consumption of Coal at Second Station.

Average number pounds of coal burned	Sundays,	December,	1893	. .	70,400
" " " " " "	"	April,	1894	. . .	62,000
" " " " " "	Week-days,	December,	1893	. . .	155,615
" " " " " "	"	April,	1894	. . .	106,680
Average Amperes,	Sundays,	December,	1893	. . . . . .	1,450 2
" "	"	April,	1894	. . . . . .	1,313.6
" "	Week-days,	December,	1894	. . . . . .	5,512.0
" "	"	April,	1894	. . . . . .	3,990.6
Average Voltage,	Sundays,	December,	1893	. . . . . .	116.6
" "	"	April,	1894	. . . . . .	116.3
" "	Week days,	December,	1893	. . . .	122.9
" "	"	April,	1893	. . . . . .	120.0

SOLUTION.

Let W = waste per hour of coal or amount used in appurtenant machines, exclusive of the steam engines. R = true rate per K. W. hour.

For December, 1893, we have:

Sundays, per hour, $2933 - W = 1450.2 \times 116.6\ R.$

Week-days, " $6484 - W = 5512. \times 122.9\ R.$

$$(6484 - W)\ 169093. = (2933 - W)\ 677424.$$

$$W(677424. - 169093.) = (2933 \times 677424.) - (6484. \times 169093)$$

$W = 1791$ pounds per hour. 19 tons per day.

For April, 1894, we have:

Sundays, $2583 - W = 1313.6 \times 116.3\ R.$

Week-days, $4445 - W = 3990.6 \times 120.\ R.$

$$(4445 - W)\ 152771.7 = (2583 - W)\ 478872.$$

$$W(478872 - 152771.7) = (2583 \times 478872) - (4445 \times 152771.7)$$

$$W(326100.3) = 1236926376 - 679070206.5$$

$$W = \frac{557856169.5}{326100.3} = 17107.\text{ pounds per hour} = 18.3\text{ tons per day.}$$

The data for the solution of the problem of the waste of this establishment has been gathered for me by Mr. A., as you see, and the numerical values in the equations for April, 1894, have been checked for me by Mr. B., in order to see if the numerical results for December, 1893, are approximately correct.

You will observe that this result of 18.3 tons loss per day very nearly checks the 19 tons loss per day as obtained by myself. The difference is probably due to the difference in temperature in two months.

In what I have to say, I will refer more particularly to December, 1893, which problem I have personally solved.

Subtracting 1,791 pounds loss from 2,933 pounds daily consumption for Sundays, I would say that the result shows 5 pounds of coal per electrical H. P. Also, taking up the question of week-days, substracting 1,791 pounds loss from 6,484 pounds daily consumption, the result shows 5.17 pounds of coal per electrical H. P. hour produced.

This is the coal used by engines and dynamos engaged in the conversion of steam power into electricity, and it is a very good result for non-condensing engines, such as we have with our very poor quality of coal.

DISCUSSION.

Mr. George H. Barrus.—Mr. Hale's interesting paper brings forcibly to notice two points of great practical and commercial value regarding the design and operation of steam plants for electric work.

The first of these is one pertaining to the provision of *cheap* engines, instead of *costly* ones, for relay power, and for use during the short periods of heavy load; and the other, to the great loss, due to leakages and careless handling, in steam plants which are engaged in the ge eration of electricity.

In a case like the Edison Company's plant, where the generating stations are divided up into a number of individual plants distinct from each other, where the feeder mains can be interconnected and the various plants operated as one complete whole, and where, as it happens, the machinery in one place is of the most economical type, while in another it is wasteful, the conditions lend themselves most readily to dividing the work, so that the constant load may be carried by the economical though costly engines, while the excessive heavy loads can be taken up and carried by the less economical engines. But the same principle can be profitably carried out, it seems to me, in any large individual station where the driving plant is made up of a number of engines. The design of such a station, embracing say half a dozen units, to be consistent throughout, would provide that the engines should be duplicates of each other. If it was thought best to employ high pressure and the most economical system of expansion, the same design would be carried out on each of the six units, so that whatever engine is brought into use it would work with the highest economy attainable. To be consistent in the design, I say, this is the plan which would be followed, although the high class engines would be much more expensive to install than a type which would consume more coal. But the days when consistency in design is the main thing to be considered are long past, and the important thing in steam and electric machinery nowadays is to get the most return for money invested, whether this be for non-condensing slide-valve engines which may use 50 pounds of steam per horse-power per hour, or from high pressure triple expansion jacketed condensing engines which may work on 11 pounds of steam per horse-power per hour. There may be some difference of opinion as to what class of engine is in the long run the most economical. Whatever this may be, it is easy to see that it is hardly worth while to install a costly engine for the sole purpose of a relay and for assistance to the main source of power during the short time when the heavy load is on, or during times of emergency, for during a large portion of the time the relay machinery is standing idle, or, at best, only partially loaded. It seems to me that these relay engines should be installed with a view to obtaining the largest amount of power with the least expenditure of money for the plant, and not with a view to economizing steam, for the question of fuel economy in this case is one of comparatively small importance.

The leakages and other losses due to improper handling in a steam

plant, composed of a number of units in accordance with electrical lighting practice, prove to be a serious matter, especially where the plant is carelessly handled. The multiplicity of parts, and the great number of valves and other complication in the connecting pipes which are required, makes it easy for such losses to go on, where in a more simple steam plant composed of only one engine they could be more easily detected and prevented. For this reason much greater watchfulness is required than in ordinary steam engineering work, and, consequently, in the absence of such watchfulness the trouble is greatly augmented. The extensive use of high pressure also contributes to increased leakages, for the reason that valves and fittings become disordered with high pressures much more quickly than otherwise, and when thus disordered the loss from leakage is much greater than with the same amount of disorder under a lower pressure. In the ordinary run of electric light stations I dare say that it would be a surprise to the engineer in charge if he were to know how much steam was wasted from his plant by leakage. In almost any case if he were to shut the throttle valves of his engines, making no other change than to stop the supply of steam to the cylinders, and, at the same time, keep one of the boilers in operation with a view to maintaining the regular pressure and keeping up a supply for whatever leaks there might be, he would find that a considerable quantity of coal would still be burned to make up this loss. The leakages through throttle valves, drip valves, separator traps, stop valves for connecting pipes, and through the many other branch pipes connected with the steam system which are provided for convenience in the operation of the station, some of which might be in a disordered condition, is, under the ordinary working practice, a large quantity. Mr. Hale's paper brings this fact out, and shows that even in a plant where every precaution is taken to obtain good service, as evidenced in the Edison Company's work, the same trouble exists, and it is of vital importance.

There is another point which concerns the economy of the boilers, and that is the loss due to banking fires. A fire may be banked and the boiler kept in condition for future work with very little loss of fuel, but this cannot be done unless the doors are closed and the damper is shut off so tightly that no cold air passes through from the furnace to the chimney. In the common practice this does not occur, for even with the damper nominally closed there is enough opening to produce a considerable current of cold air through the structure, and the result is that the boiler is cooled down, the inrush of air burns up the coal in the bank, and the loss thus sustained must be made good by the use of fresh coal, when the boiler again requires to be set to work.

SOLID FLOORS FOR RAILROAD BRIDGES.—THEIR MERITS AND THE CALCULATION OF THEIR STRESSES.

By Henry Goldmark, Member of the Western Society of Engineers.

The iron and steel bridges erected on American railroads, during the past few years, undoubtedly show a great improvement over the older designs. The changes consist in the use of simpler and better forms of construction, combined with a marked increase in the weights of the spans.

In fact, as far as the principal members are concerned, the cross-sections in our latest bridges are of ample size, and the unit strains are very moderate.

Few engineers will question the wisdom of thus providing a liberal amount of material to withstand the shocks and vibrations of rapidly moving trains. We must not forget, however, that the proper dimensioning of the truss members and the floor girders is after all only one part of a bridge design. The choice of the most advantageous form and depth for the trusses, the selection of a proper floor system, and, last but not least, the design of the details and connections are of even greater importance.

Undoubtedly, improvements have been made in all these points, but a candid observer can hardly doubt that there is need of much further progress. It has indeed been asserted, quite recently, and on excellent authority, that the evolution of the railroad bridge is practically completed, but history and the observation of present practice, alike refute any such theory of perfection.

It is, on the contrary, perfectly clear, that much work remains to be done in investigating the problems involved in bridge design and the best methods of solving them, before we can hope to succeed in building thoroughly rigid and durable as well as safe structures.

Railroad bridges may be divided into two classes, the requirements for which are widely different.

There are, on the *one hand*, large bridges, consisting generally of several spans of considerable length, and crossing important rivers. In such structures the dead weight of the iron work will necessarily be great, while the speed of the trains is likely to be moderate. The truss work of these long spans will be subjected to strains of essentially the same character as those produced by quiescent loads. Within reasonable limits the use of long panels and high trusses will not be objectionable on practical grounds, while it will, of course, produce a high degree of

economy. The advantages of pin connections, too, can be obtained without any accompanying drawbacks. Moreover, as the speed of the trains is slow, the floor system will not be subjected to excessive strains from impact, while derailments will rarely occur. In such bridges, economy of material is eminently desirable from every point in view, so long as the prescribed strength is maintained.

On the other hand, we have the great bulk of our railroad bridges, viz.: the shorter spans which form an integral part of our railroad lines. They are of moderate length, few of them being over 150 feet long, and are habitually passed over by trains at full speed.

The conditions to be met in designing such short spans are evidently very different from those to which bridges of the first class are subjected. Their length being small, the impact of the live load on all parts of the iron work is violent, and great care must be taken to minimize its effects. Mathematical analysis is of little service in settling the questions involved. The static forces contained in ordinary strain sheets are by no means a measure of the work the metal has to do, while the more complicated theories on secondary and impact strains are as yet scarcely in a shape fit for practical use. The engineer's judgment based on practical experience, and a study of bridges under the action of traffic, will have to be the main guide in designing.

Fortunately, iron railroad bridges have been in use long enough and in sufficient numbers to give an inductive method of this kind a good chance of application. Those bridges which have actually failed while in service, as well as others that have been replaced for structural weakness, present abundant material for criticism and study.

For short spans, more than for any others, the aim of the designer should be to produce a structure which shall act, as far as possible, as a single unit, with the least possible movement of the separate parts, as well as of the bridge as a whole. All types of truss, and all details and connections, which conflict with this requirement must be discarded. Economy should, of course, be studied, but it will be found to consist rather in using such forms as are simple in detail and easy of construction than in striving to reduce the weight of metal used to a minimum. As an increase in the weight of the iron work and the flooring is the most efficient means of absorbing shock and decreasing vibrations, any additional metal in a short span is of decided advantage, and the expense involved is usually small as compared with the total cost. In connection with this matter, it must be remembered that the actual expense of the shop work remains almost the same even though the weight of the sections be considerably increased. At the present time, steel shapes for bridge-work can be bought at the Pittsburg mills for a price barely exceeding one cent per pound, so that to adopt an economy of material,

which may shorten the life of the structure, appears more than ever a short-sighted policy.

A neglect of the above considerations was, however, quite general in American iron bridge-work at no remote period in the past. The sound practical judgment which had given to the world such valuable constructions as the Howe truss and the timber trestle seemed for some years entirely set aside, and the desire for an extreme economy superseded all other considerations in the design of iron bridges. To this period belongs a type of bridge, unfortunately not yet extinct on American railroads, in which the requirements of rigidity were almost wholly disregarded. Even for the very shortest spans the use of eyebars and rods connected by small pins was universal in the trusses, while the lateral and floor systems were connected in the loosest possible way. On a well-known Western railroad, the writer recalls examining a sixty-foot iron deck span, which was made up of some three hundred separate members and details connected by pins. The vibrations of this bridge under a moving train were quite alarming, although the sections of the truss members were in virtual agreement with the usual strain-sheet requirements.

Of late years, as is well known, the merits of plate girders for railroad work have been more fully appreciated, and this excellent form of construction has come into general use up to lengths of 80 and even 100 feet. For longer spans the riveted lattice type is constantly growing in favor, and is likely to become the standard form for all ordinary railroad bridges. The experience of those American railroads that have adhered to riveted connections from an early day has been a very satisfactory one, while European practice has been wholly on this line. It seems to the writer that this development of truss construction is the best possible one for obtaining rigidity in our bridges.

With regard to the *floor system*, it may fairly be said that its proper design is of even greater importance than that of the trusses. It is that part of the bridge with which the engine and train loading first come in contact, and all its details and connections are subjected to violent strains. It also serves to tie the two trusses together, and thus forms an important part of the lateral bracing. Any increase in the engine weights affects the short girders of the floor system far more seriously than any other part of the bridge. In fact, a decrease in the wheel base alone, without any change in the total loading, may have a dangerous effect on the floor. As an instance of this, the writer may mention a case in his practice where by merely shortening by *twelve inches* the driving wheel base of a ten-wheel engine the strains in the floor-beams and stringers were increased fully twenty per cent. For this reason the floor system is usually the first part of a bridge to be overstrained by the introduction of new types of locomotives.

The main defects of our ordinary floor systems, however, lie much deeper than in the mere scant proportioning of the sections, and are more difficult to remedy. While most floors are strong enough to carry an engine and train safely under normal conditions, few will do so when any part of the train is derailed or in "bad order." It is indeed often maintained that a bridge floor is intended to carry a train when it is on the track and not on the ties, and that the engineer's task is fulfilled when he has built a structure capable of doing so. This explanation of, or apology for, bridge failures, absurd as it is, has often been heard, even from men directly engaged in designing bridges.

The point at issue is a severely practical one. The railroad manager and the traveling public are right in asking that the railroad bridge, like any other tool, should be capable of accomplishing such work as it is liable to be called upon to do during its life.

As a matter of fact, the occurrence of a broken brake rigging or axle, a cracked wheel or a derailed truck, are conditions likely to confront it at every movement.

We cannot be asked to do what is impossible, but if a floor system can be designed which will be safe even under such untoward conditions, it is clearly our duty to provide it.

A safe bridge floor should be, what it was called by the early English engineers, a *platform, i. e.*, an unbroken surface from one end of the span to the other, strong enough and rigid enough to support a moving or even a derailed train at any point. If the floor meets these requirements, it will go far towards making a total collapse of the bridge structure impossible. It will, perhaps, be objected that a derailed car is likely to strike the trusses before reaching the edge of such a platform, so that it is unnecessary to provide an unbroken deck of full width. But even when this occurs, the car is sure to do less injury to the trusses, if it is properly supported on the top of the floor, than it would be when dropping through the gaps of an open or discontinuous flooring.

Even the best of our ordinary floor systems do not, in the opinion of the writer, conform fully to the requirements laid down above, while on the majority of railroads there are at least some spans with very defective floors. In the United States, timber was for a long time the sole material in use for the stringers, ties and guard-rails of bridges, and in many cases for the transverse floor-beams as well. Of late, iron rolled beams or short plate girders have replaced the wooden stringers, though for ties and guard-rails timber is still universally used. There is no doubt that with a proper proportioning and spacing of the stringers and ties, and securely fastened guard-rails, timber floors can be built which will be fairly safe as long as the timber is new. As a matter of fact, the ties are too short and spaced at too great intervals on most

bridges, while the arrangement of the guard-rails is faulty, so that a derailed train finds but little support.

To be entirely secure, there should be, at least, four lines of iron stringers, the outer ones being close to the trusses, and strong timber ties spaced very closely, preferably with openings not exceeding four to six inches. The guard-rails should consist of iron or of timbers protected by iron angles, and it is desirable to have an inner as well as an outer rail. A floor of this kind will necessarily be somewhat expensive and difficult to renew; the danger from fire will always be present, and its life will rarely exceed eight to ten years. With heavy engines, the rails are likely to cut into the ties, and the rail fastenings to become loose. As a whole, even the best timber floors will be far from fulfilling all necessary requirements as to safety and durability.

Of late years, *solid* or *continuous* floors of iron or steel have come into use on a number of American railroads, though generally only in exceptional cases. In England they have for many years been extensively employed. They consist, as a rule, of a series of troughs running transversely to the main girders or trusses, to which they are fastened. In some cases the troughs are replaced by rolled beams, closely spaced and connected by a continuous iron plate. The rails are either fastened directly to the iron troughs or to timber cross-ties. In the latter case there is often a ballast filling, so that adjustments in the track can be made by tamping.

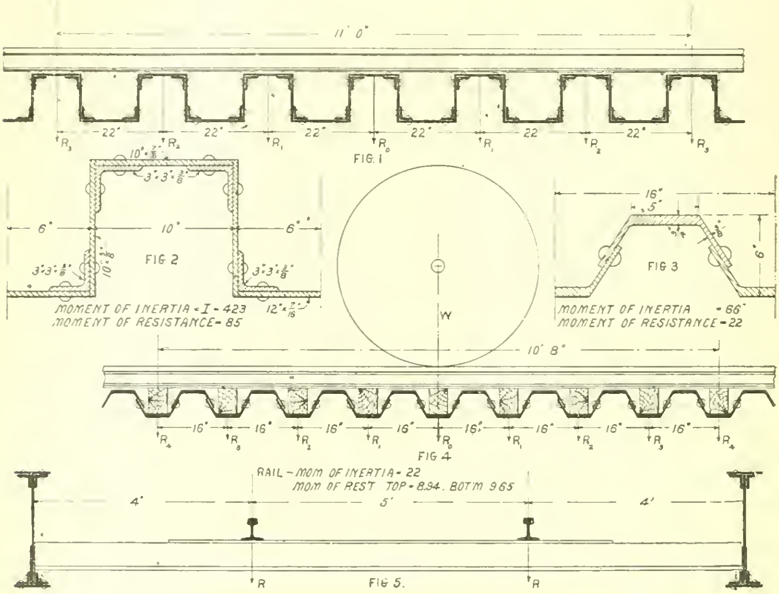
The best of these constructions possess, in the opinion of the writer, many advantages over timber floors, with but few drawbacks, while their expense is not unreasonably great. They present an unbroken platform or surface, equally strong at all points, and besides this, form a very rigid system of lateral bracing between the trusses. There is also the incidental advantage that the tracks may cross the floor at any angle, so that frogs and switch connections can be placed anywhere on the bridge. Where a very shallow floor is a necessity, the trough construction is often the only feasible form. The avoidance of fire risks is, of course, an additional recommendation for iron as compared with a timber floor.

While the solid floor is still something of a novelty in America, it is likely to be used more extensively in the future, as it possesses great merit as compared with other forms.

As a matter perhaps not devoid of interest, the writer begs to present some computations made by him on certain types of solid floor during the past year or two. It is believed that the theory of strains involved may offer some points of value, apart from its application in practical designing.

The forms selected are shown in Figs. 1 to 5, in which the

troughs with inclined sides (Figs. 3 and 4) represent the shapes used by the Illinois Central Railroad on its elevated tracks in the city of Chicago, while the square troughs were adopted by the Lake Shore and Michigan Southern and the Chicago, Rock Island and Pacific Railroads, for similar work constructed in 1894.



The mechanical theory of *least work* was first applied to the calculation of the strains in solid floors in a very interesting and valuable article on the subject, published a year or two ago, with examples from English practice.*

As in all structural work, there are two points to be determined:

(*a*) The maximum stress that will occur in any part of the structure under the applied loads.

(*b*) The deformations and deflections accompanying such strains.

The solution cannot be obtained in this case by statics alone, as it involves some considerations which belong to the theory of elasticity.

Taking the floor shown in Fig. 4, we have evidently a combination of a certain number of transverse beams 13 feet long, supported on the main girders, and two longitudinal beams, viz., the track rails. If W represents a wheel-load directly over one of the troughs, this trough as well as the rail at this point will deflect a certain amount. The rail in its turn, will depress the troughs at either side, and thus the weight

* Cf. *Engineering* (London), September 15, 1893.

W will be distributed over a number of troughs. We have, therefore:

$$W = R_0 + 2R_1 + 2R_2 + 2R_3 + 2R_4,$$

where the number of troughs to be taken into consideration depends on the relative rigidities of the rail and the troughs. The problem then resolves itself into finding out in what proportion W is carried by the different troughs; when this is known the strains in the troughs and the rails can be computed by the ordinary theory of beams.

By the *principle* of *least work* we can conclude at once that the distribution of loading will be such that the total work done in deforming the rails and the troughs will be a minimum. It remains, then, to find an expression for this work of deformation and from it to deduce R_0, R_1, R_2, etc., in terms of W. By a formula due to *Euler*, we know that, for any beam of uniform cross-section and materials

$$\text{The Work of Bending} = \frac{1}{2EI}\int M^2 dx$$

where M = Bending Moment of External Forces

E = Modulus of Elasticity,

and I = Moment of Inertia.

Applying this formula to our case.

The work of bending one trough under two loads R (Fig. 5)

$$= \frac{1}{EI}\int_0^{48} R^2 x^2 dx + \frac{1}{2EI}\int_{48}^{108} 48^2 R^2\, dx$$

Which by integration substituting for I its value = 22

$$= 1606\ \frac{R^2}{E}$$

This formula may be proved as follows:

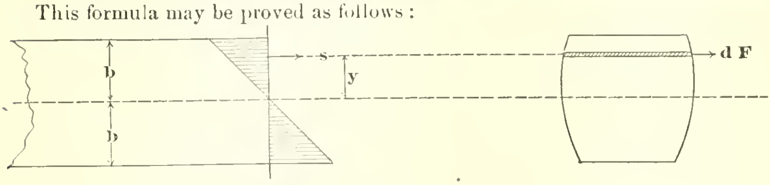


Fig. 6.

If Fig. 6 represents a beam cut at any point,

Let dF = an elementary area at a distance y from the central axis.

s = unit strain on dF.

Then sdF = total force acting on dF.

$\frac{sdx}{E}$ = elementary distance passed over by this force; and work done =

$$\tfrac{1}{2}\, sdF\ \frac{S}{E}\ dx$$

which for the whole cross-section =

$$\frac{1}{2EI}\ M^2 dx.$$

This expression when integrated for any given length of the beam gives the form in the text.

Hence if U_T = work of bending all the troughs

$$U_T = \frac{1606}{E} (R_0{}^2 + 2\,R_1{}^2 + 2\,R_2{}^2 + 2\,R_3{}^2 + 2\,R_4{}^2)$$

Or, by substitution, since $R_0 = W - 2\,R_1 - 2\,R_2 - 2\,R_3 - 2\,R_4$

$$U_T = \frac{1}{E} (1606\ W^2 + 9636\ R_1{}^2 + 9636\ R_2{}^2 + 9636\ R_3{}^2 + 9636\ R_4{}^2 + 12848\ R_1\,R_2 + 12848\ R_1\,R_3 + 12848\ R_1\,R_4 + 12848\ R_2\,R_3 + 12848\ R_2\,R_4 + 12848\ R_3\,R_4 - 6424\ WR_1 - 6424\ WR_2 - 6424\ WR_3 - 6424\ WR_4).$$

Again from formula (A):

If U_R = work of bending the two *rails*,

$$U_R = \frac{2}{EI} \left(\int_0^l M_1{}^2 dx + \int_0^l M_2{}^2 dx + \int_0^l M_3{}^2 dx + \int_0^l M_4{}^2 dx. \right)$$

Where $M_1\ M_2\ M_3\ M_4$ are bending moments in the different panels of the rail.

The rail is here a continuous girder with reactions at the supports $= R_0, R_1, R_2, R_3$ and R_4, respectively, so that we can write

$$M_1 = R_4\,x$$
$$M_2 = R_4\,l + R_4\,x + R_3\,x$$
$$M_3 = 2\,R_4 l + R_3 l + R_2\,x + R_3\,x + R_4\,x$$
$$M_4 = 3\,R_4 l + 2\,R_3 l + R_2 l + R_4\,x + R_3\,x + R_2\,x + \ldots$$

where l = the panel length = 16 inches.

By reduction we have:

$$U_R = \frac{1}{E} (3972\,R_4{}^2 + 1676\,R_3{}^2 + 497\,R_2{}^2 + 62\,R_1{}^2 + 1738\,R_2 R_3 + 497\ R_1\ R_3 + 310\ R_1\ R^2 + 5027\ R_3\ R_4 + 2483\ R_2 R_4 + 683\ R_1\ R_4).$$

Hence if $U = U_T + U_R$ = total work done.

We can write:

$$U \frac{1}{E} (1606\ W^2 + 13608\ R_4{}^2 + 11312\ R_3{}^2 + 10133\ R_2{}^2 + 9698\ R_1{}^2 + 13158\ R_1\ R_2 + 13345\ R_1\ R_3 + 13530\ R_1\ R_4 + 14586\ R_2\ R_3 + 15331\ R_2\ R_4 + 17875\ R_3\ R_4 - 6424\,WR_1 - 6424\ WR_2 - 6424\ WR_3 - 6424\ WR_4)$$

This is a function of $R_4\ R_3\ R_2$ and R_1 and will be a minimum when all the partial derivatives are equal to zero.

Differentiating we have:

$$\frac{dU}{dR_4} = \frac{1}{E} \left(27216\ R_4 + 17875\ R_3 + 15331\ R_2 + 13531\ R_1 - 6424\,W \right)$$

$$\frac{dU}{dR_3} = \frac{1}{E}\left(17875\,R_4 + 22624\,R_3 + 14586\,R_2 + 13345\,R_1 - 6424\,W\right)$$
$$\frac{dU}{dR_2} = \frac{1}{E}\left(15331\,R_4 + 14586\,R_3 + 20265\,R_2 + 13158\,R_1 - 6424\,W\right)$$
$$\frac{dU}{dR_1} = \frac{1}{E}\left(13531\,R_4 + 13345\,R_3 + 13158\,R_2 + 19396\,R_1 - 6424\,W\right)$$

Equating these to zero and reducing we have:

$$\begin{aligned}
424\,R_4 + 279\,R_3 + 239\,R_2 + 210\,R_1 &= 100\,W\\
279\,R_4 + 362\,R_3 + 227\,R_2 + 208\,R_1 &= 100\,W\\
239\,R_4 + 227\,R_3 + 316\,R_2 + 205\,R_1 &= 100\,W\\
210\,R_4 + 208\,R_3 + 205\,R_2 + 302\,R_1 &= 100\,W
\end{aligned}$$

These simultaneous equations may be solved without any especial difficulty and give:

$$\begin{aligned}
R_0 &= .192\ W.\\
R_1 &= .173\ W.\\
R_2 &= .120\ W.\\
R_3 &= .080\ W.\\
R_4 &= .031\ W.
\end{aligned}$$

By the same method we get for the second type (Figs. 1 and 2):

$$\begin{aligned}
R_0 &= .39\ W.\\
R_1 &= .26\ W.\\
R_2 &= .09\ W.\\
R_3 &= -.045\ W.
\end{aligned}$$

Having thus obtained the proportion of a single concentrated load carried by the different troughs, the calculation may readily be extended to any system of axle loads desired.

In practice the driving-wheels of engines are rarely less than five feet apart, and we may suppose a wheel to be placed at every fourth trough in Fig. 4, or every third trough in Fig. 1.

Combining the percentages of W, which are thus concentrated on the different troughs, we find that the distribution of the loading over all the troughs of the floor will be nearly uniform. In other words, in the first case each trough carries one quarter of the wheel load, and in second case, one third. These results enable us to compute the greatest strains likely to occur in any one trough with a degree of accuracy fairly comparable with that obtained in the other parts of bridges. It may indeed be objected that the stiffness of the rail is depended upon to a greater degree than is proper, but it is doubtful whether the conditions under which the rail acts on a bridge of this kind are not more favorable to its life than those met with on the rest of the road-bed.

A further point has been raised as to the effect of an inefficient rail joint on the distribution of the loading. Some computations have been made by the writer on this point. In order to make the case as unfavor-

able as possible, the joint plates have been supposed to be entirely removed. The result of the computation indicates that even in this case the maximum load on a trough is but slightly increased over the proportions tabulated above.

In some cases, moreover, additional iron rails, or deck beams and angles, have been used as guard-rails, which are of course quite efficient in distributing the load longitudinally.

It is beyond the scope of this paper to discuss at length the different forms of solid floors or their relative strength.

The question of depth is often decided by local considerations which govern special cases. As shown by a comparison of the two cases considered above, the shallower floors distribute the loading more widely and thus reduce the strains and lead to an economy of material. They are, however, not very stiff under trains, and this lack of rigidity, though perhaps advantageous to the rolling stock, may tend to loosen the rivet connections or even the track fastenings. The deeper floors concentrate the loading so that each trough contains more metal, and the floor is made more rigid even if it is not stronger than one of lesser depth.

It seems advisable on the whole not to go below a depth of nine or ten inches for the floors of single-track bridges, at least under such heavy train-loads as must usually be provided for.

DISCUSSION.

Mr. Wallace.—Mr. Goldmark has evidently overlooked the fact that the C. M. and N. Division of the Illinois Central has five bridges, having the style of floor mentioned in the first part of his paper, or a similar style, that have been in service five years. This floor was designed, under the general direction of Mr. E. L. Corthell, by Mr. A. F. Robinson, and was used in five bridges on what is known as the Clyde viaduct, where the Illinois Central crosses the Chicago, Burlington and Quincy Railroad, west of the city. One of these bridges is a 150 feet span; the other four are plate girders. The depth of the trough was 12 inches, and made substantially square, as shown on drawings. The tie, however, rests on a reversed angle placed 6 inches below the top of the trough; the tie being 8 inches in thickness, the rail rests on the tie, clearing the ironwork 2 inches, the tie serving as a cushion between the bridge floor and the rail. This floor is very stiff and has given satisfactory results. This trough section of floor (indicated on drawing), the design mentioned by Mr. Goldmark as being used on the bridges over the streets on the Illinois Central elevated work through Hyde Park, was adopted on account of its being a commercial section that could be easily and quickly procured; as, after the railroad company decided to do this work

there only remained nine months to design and construct the bridges, and it was found the work would be delayed in case any other design was used. It was therefore not considered advisable to make a special design and run the risk of delay.

In the original plan the ties rested on the bottom of the troughs, as indicated by Mr. Goldmark, it being the intention to bed the ties in a preparation of asphalt or asphalt concrete, in order to deaden the noise and preserve the ties It was afterwards found, however, that this work could not be contracted for at less than $1.25 or $1.50 per tie, and that no track could be spared from service for our own men to do the work, and the plan was abandoned, the ties being permitted to rest on the bottom of the troughs as indicated in the drawings. The ties are now being taken out of the troughs and shifted so as to rest on top of the sections, enabling the troughs to be regularly cleaned out and properly painted.

While these floors have given very satisfactory results, and after sixteen months' hard usage we have found no loose rivets, the present plan will add strength to the floor, and is expected in some measure to relieve the strain on the rivets. Our fast suburban trains are now passing over this floor at 10 to 15 minutes intervals and at speeds of from 45 to 50 miles an hour. The traffic on the other tracks is heavy and continuous.

The additional reason we had for taking the ties out of the troughs and putting them on top of the sections was to relieve the rail from the liability of contact with the iron by cutting into the ties, as when the ties remained in the troughs there was only a fraction of an inch clearance, and as we are using the track circuit for the operation of our block signals the rail coming in contact with the iron would interfere with the satisfactory operation of these signals.

Mr. W. R. Roberts.—I would like to ask how high the ties are?

Mr. Wallace.—Six inches.

Mr. Bainbridge.—I would like to ask if you have any trains off the tracks under those conditions?

Mr. Wallace.—No.

Mr. Roberts.—I would like to ask what the deflection was?

Mr. Goldmark.—In this case the deflection was less than half an inch.

Mr. Roberts.—That is under the rail?

Mr. Goldmark.—Yes.

Mr. Lundie —In Mr. Goldmark's equation he equates the work done by W to the work done by rail and troughs. There is the work done by the girders, the structure being elastic and having deflection, Now, do you take any account of the ties, or do you consider they distribute the work uniformly along the troughs. Will not that form an important element in figuring the deflection?

Mr. Goldmark.—It would, but the deflection is so slight, I did not introduce the deflection in the calculation of that work at all.

Mr. Lundie.—Take the work of the tie, will it not affect the result?

Mr. Goldmark.—Yes; but it will be favorable; the deflection will be even less.

Mr. Wallace.—I understand that you did not take into consideration the work of the tie itself at all?

Mr. Goldmark.—No; I did not. That would make each girder a little bit stronger than it would be otherwise. Just how much I do not think it would be easy to say, but it will make all the expressions a little stronger.

Mr. Wallace.—In connection with the ties I would like to make this remark, that the girders along the Illinois Central are generally placed 13 foot centers, and several times we have changed our tracks from one space to another, and in one case we were not able to get our iron floors for them, and we support our tracks over these openings by stringers, which are virtually ties, resting on the flanges of the girders here (indicating shelf angles), and not having solid floors. We are using 12 x 12 and 8 x 16-inch ties, they are ties or floor-beams, whatever you may call them, resting on the bottom flange here. (Indicating shelf angles.)

Mr. Horton.—I wish to place myself on record in support of Mr. Goldmark's suggestion that bridge designs should be simple, using material from the rolls in large sizes rather than small. If a flange of a girder requires a total section not exceeding what may conveniently be procured in two angles, use two angles only. Relieve the girder of stiffeners; except where there is some reason to suppose they are useful. Put the weight of useless stiffeners into extra thickness of web or other parts, to the end; that the structure shall be better prepared to resist shocks as well as destruction caused by rust.

Following this line of thought, I think a clause introduced in specification, requiring all metal to be at least ½ inch thick, would be in the right direction. Mr. Goldmark's investigation would lead to the conclusion that the quite general specification (for timber ties laid on stringers, say, 1 foot 4 inch centers), that three ties be assumed to carry a full wheel load, is satisfactory, in fact fully justified by the investigation.

In the solution of equations as they appear from Fig. 4, and assuming an additional wheel load placed at R_4, both right and left, we discover that the rail is called upon to act as a continuous beam 5 feet 4 inches between supports, resulting in nearly equal distribution of the load on the points R_0 R_1 R_2 R_3 R_4.

With a wheel load of 36,000 pounds at R_0, and also at R_4, both

right and left, we shall have at R_0 9,144 pounds; at R_1 9,108 pounds; at R_2 8,640 pounds, and at R_3 9,108 pounds, aggregating one wheel load. That is, with the assumed rail section and assumed floor (precession of wheels quite as actually used), a variation is shown in the load on all the troughs of only 504 pounds. If this is a fact it appears the rail is called upon to do a very considerable amount of labor as a beam.

The two solid floors shown have taken very different directions in design, one using ties of timber, in the other, rails being secured directly to the metal work. Also attachment of floor to girder is one of further radical difference; one rests upon shelf angles, the other has connecting angles with oblique gussets.

Another point in connection with the solid floor. Shall the floor be water-tight, as in the two examples shown by Mr. Goldmark? My attention has been called to a track elevation ordinance in another city, where it is specifically stated that the floor shall be open to allow light to pass through. The open construction will more than likely be most in favor as best serving all questions of stability as well as durability

It is my understanding that solid floors, as used in Europe and generally in this country up to the present time, have had track with ties, with or without ballast. The tendency to rust under the ties and ballast without chance for inspection has developed a modified design.

The distance from base of rail to clearance, where solid floors are used, is material, the demand in most cases is for very narrow limits.

Some months since I had occasion to work out a solid floor, using I-beams—the sketch shows the design—the flange of the I-beams, top and bottom, being open for inspection.

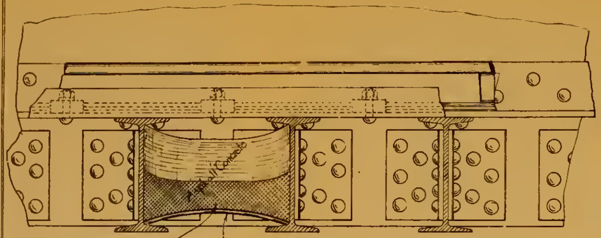
Considering the I-beam in connection with the various requirements for solid floors: It will allow the floor to be as shallow as any section. It may be an open construction by simply leaving out the concrete filling, or water-tight with the filling. It may be set on shelf angles or secured by conneting angles, or carried by oblique gussets. It will take less pounds of material than any other form suggested. It will require materially less work in the shop, and certainly no more in the field than the various other methods proposed.

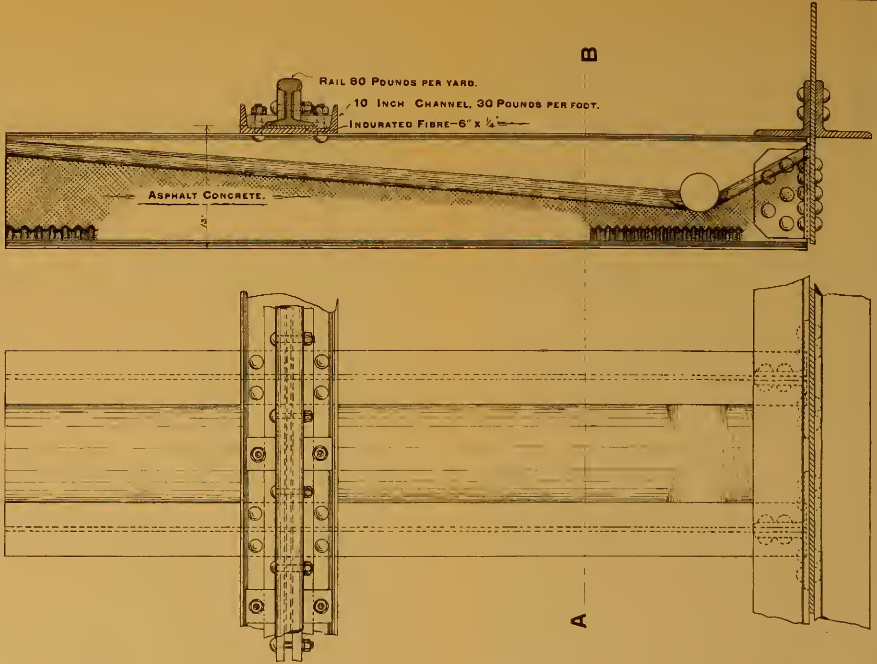
Indurated fibre between the rail and the channel is proposed, first to reduce the wear on the rail fastenings, second, to reduce noise. The continuous splice bars are proposed as somewhat of a safeguard against a broken rail.

It may be urged that I-beams spaced anywhere from 12 to 18 inches center to center, the flange of the beam reducing the space at least 5 inches, does not make a very solid floor; however, as the openings are necessarily at right angles to the direction of traffic, a wheel off the track will roll better across openings of 12 inches than of 12 feet.

With I-beams it is entirely feasible to rivet plates the entire width and length of structure on the top flange of beams, making a solid surface for a derailed train, or the plate may be riveted on the bottom flange. In fact, the I-beam, or the I-beam in combination with plates, furnishes material in shape to form support of track without ties, with greater economy than any other form suggested. It may be a misfortune that there is no patent connected with its use, because if backed by patent it would be promoted.

Mr. Goldmark's conclusion that the more elastic floor has advantages in distributing load is true with continuous rail of certain stability acting as a continuous beam; however, there must be limits as to the elastic floor's advantage for distributing weight through the rail, because the rail is of uncertain rather than certain stability, and is not continuous.





SOLID FLOORS FOR RAILROAD BRIDGES

WESTERN SOCIETY OF ENGINEERS

DESIGN FOR SOLID FLOOR

By H. E. HORTON

THE DE KALB ELECTRICAL PUMPING PLANT.

By Daniel W. Mead, Member of the Western Society of Engineers.

[Read before the Society, May 14, 1895.*]

De Kalb, Ill., is a city of about 5,000 inhabitants and lies on the main line of the Chicago and North Western Railway about sixty miles west of Chicago. De Kalb has had a system of water works since 1879, but as it was the result of circumstances rather than intelligent design it was far from satisfactory. In 1872 the agitation in favor of water works first began and a deep well 4½ inches in diameter was sunk to a depth of 1,000 feet. No flowing water was obtained and the well was considered practically a failure, although a pump and wind mill was soon after erected.

In 1878 it was decided to drill deeper in the hopes of striking flowing water, and another well 4½ inches in diameter was sunk to a depth of 2,469 feet, but no flowing water was encountered.

The failure to secure flowing water at De Kalb is due to the fact that De Kalb is one of the highest points in Northern Illinois. The surface at the location of these wells is about 897 feet above sea level, while the artesian waters at Rockford, about thirty miles northwest of De Kalb, have never risen from the Potsdam sandstone to a higher level than 741 feet above the sea, or from the St. Peter sandstone to about 705 feet above sea level. The water in the De Kalb wells, however, now stands at about 772 feet above sea level, or about 125 feet below the surface of the ground at the old pumping station, which is much higher than would be expected from results obtained in other places.

In 1878 a contract was made for an engine, boilers and elevated tank, and the first public supply for fire purposes dates from the completion of this contract in 1879. The wells as drilled were found to be too small, and in 1882 a 6-inch well was drilled 800 feet deep to the St. Peter sandstone, and a Deane direct-acting steam deep-well pump was purchased to raise water from this well. A standpipe 22 feet in diameter and 80 feet high was also built in 1890, and into this the deep-well pump raised the water. The water mains consist of about 2,500 feet of 6-inch cast-iron pipe and about 24,000 feet of 4-inch cast-iron pipe, with numerous hydrants and a very few valves.

On May 29, 1893, the City Clerk reported the cost of the water works plant to be as follows:

* Manuscript received July 17, 1895.—*Secretary, Ass'n of Eng. Socs.*

First well	$4,050 00
Second well	14,4[illegible] 00
Engine, boiler and tanks	4,27[illegible] [illegible]0
Third well	4,000 00
Standpipe	8,000 00
Pumps, heaters, etc.	2,790 49
Hydrants and mains	19,385 45
Interest on bonds	8,046 88
Total cost	$65,002 32

The cost of operating the works for the two years prior to the construction of the new plant was as follows:

	From May, 1892, to May, 1893.	From May, 1893, to May, 1894.
Engineer and assistant	$1,140 00	$1,381 40
Repairs and supplies	323 62	266 00
Extra labor	70 65	70 35
Incidentals	30 55	. . . .
Electric light	108 53	113 12
Coal	$1,350 71	2,019 80
Total operating expenses	$3,023 52	$3,850 67
Revenue	2,637 97	2,715 17
Deficiency	$385 55	$1,135 50

The average pumping record was as follows during this time:

Hours pumped per day	15	22
Gallons pumped per day	85,260	98,652
Cost per 1,000 gallons pumped	9.8 cents.	10.8 cents.

Cost of coal about $2.40 per ton of 2,000 pounds.

From the above it will be seen that while the revenues were not materially increasing, the operating expenses were rapidly increasing, and the cost of pumping per 1,000 gallons had increased about 10 per cent. The plant was in operation an average of twenty-two hours per day through the years 1893 and 1894, and during the warm weather it ran continuously, except when necessary to shut down for repairs. In the extremely dry summer weather it became necessary to shut off the water entirely, with the exception of an hour each at morning, noon and night, in order that water might be kept in the standpipe for fire purposes.

These were the circumstances when the writer was called in to suggest some remedy whereby a sufficient amount of water could be secured and the works put on a paying basis.

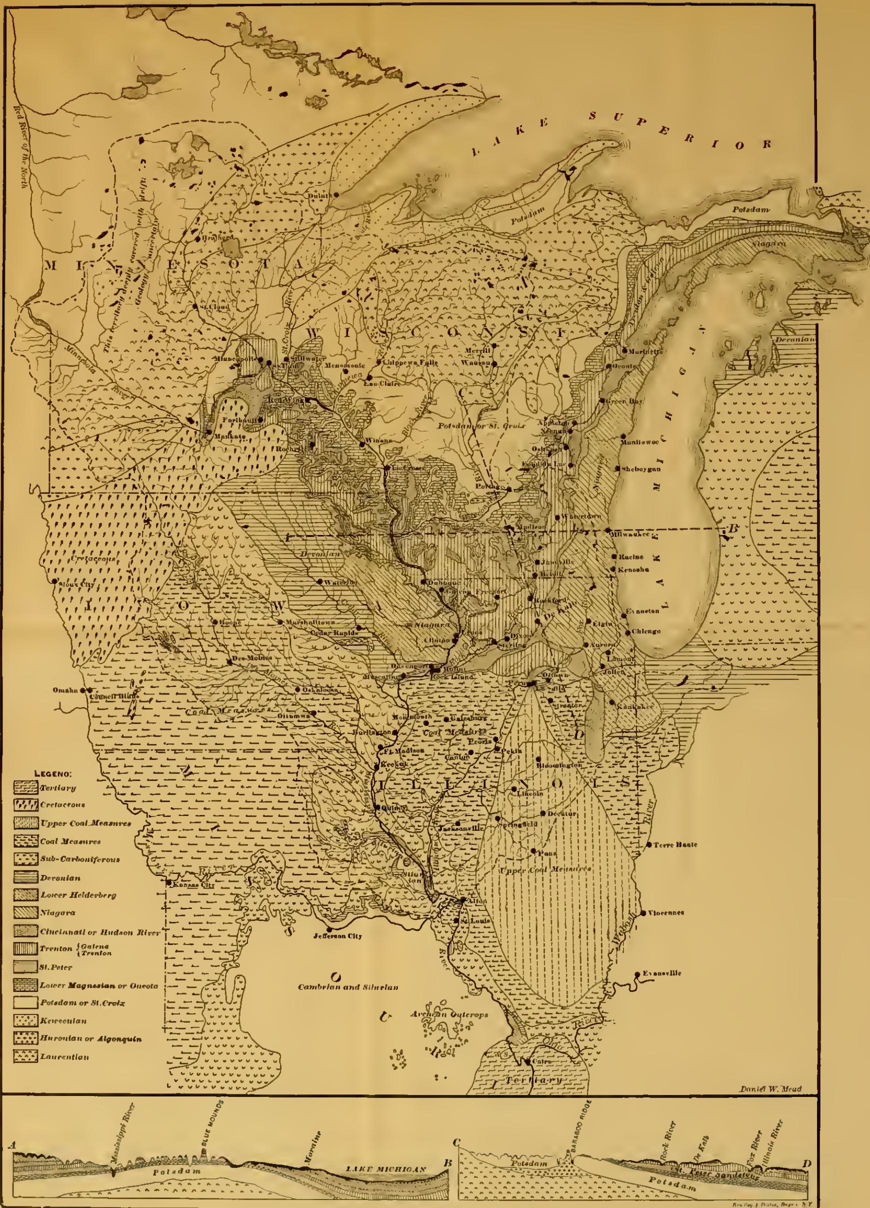


FIG. 1.—APPROXIMATE GEOLOGICAL MAP OF UPPER MISSISSIPPI VALLEY, SHOWING LOCATION OF DE KALB AND SOURCE OF ITS WATER SUPPLY.

AVAILABLE SOURCES OF WATER SUPPLY.

De Kalb is situated on a branch of the Kishwaukee River, which is there, however, very small, and is dry during the summer months. No drainage areas are readily available for collecting and impounding water, as the land is quite level for a large distance in every direction from the city. In consequence the city has to depend on the underground waters for its supply.

In all cities of Northern Illinois there are three sources which can usually be made available with more or less success as sources of water supply. These are:

1. The sands, gravels and clay drift which overlie the bed rock.
2. The St. Peter sandstone.
3. The Potsdam sandstone, which contains the lowest water-bearing strata.

The waters from the St. Peter and Potsdam sandstones fall as rain in W[illegible]nsin on the exposed outcrop of these strata, which is there at a [illegible]levation than most of the surface of the ground in Illinois. [illegible] into these strata, which have a southerly dip, the waters flow [illegible]l are reached by the drill at various points southerly from their [illegible] under considerable hydraulic pressure, in many cases giving rise to flowing artesian wells. (See Hydro-Geology of Upper Mississippi Valley, JOURNAL ASSOCIATED ENGINEERING SOCIETIES, July, 1894). The drift waters have a similar origin. Their watersheds are not, however, so marked and obvious, but are often more local and limited in extent. The map and profiles will make the sources and general condi[illegible] of these waters easily understood. (See Fig. 1.)

At De Kalb a number of private wells have been sunk into the drift, some of which give flowing waters. The water obtained, however, is quite hard and not as suitable for domestic and boiler use as the water from the St. Peter sandstone, as the following analyses, made by G. M. Davidson, Chemist, will show:

	Drift Water.	St. Peter Water.
Total solids	47.59	17.49
Carbonate of lime,	16.66	8.37
Carbonate of magnesia,	6.29	6.47
Sulphate of lime,	4.39	. .
Sulphate of magnesia,	12.25	. .
Oxide of iron and alumina,	11.12	.69
Silica	.87	. .
Alkaline chlorides,	2.33	.11
Alkaline sulphates,	4.68	1.13

The Potsdam waters are only obtained by drilling considerably deeper than for the St. Peter waters, and as the previous experience of the city did not show that any advantage was to be gained by the extra

expense involved in deep borings, the St. Peter water was selected as the source of supply for the city.

The old pumping plant was practically of no value. It had been erected on the highest ground in the city and all coal had to be hauled to it at an extra expense. The machinery was worn out or inadequate. The wells at that point were also too small to be available for the increased supply. It was therefore decided to sink a new well near the crossing of the Chicago & North Western Railway with the Kishwaukee River, where the ground was about 855 feet above sea level. The well was designed to be 14 inches in inside diameter to the rock and 6 inches in diameter in the rock to and into the St. Peter sandstone. The contract was let to W. H. Gray & Bro., of Chicago, for 14-inch casing

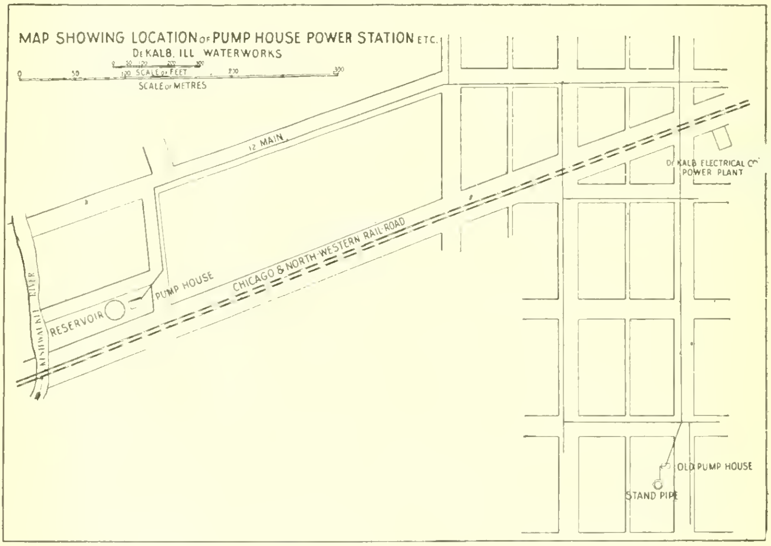


FIG. 2.

to the rock at $4.00 per foot, and a 6-inch hole in the rock at $1.95 per foot. The well drillers had great difficulty in sinking the 14 inch pipe to the rock, and were permitted by the city to reduce it at 128.4 feet below the surface, from which point to the rock 161 feet below the surface it is 12 inches in diameter. The entire depth of the well as completed was 890 feet, and the water rose to within 65 feet of the surface.

The strata encountered in drilling the well were approximately as follows:

0 to 125 feet, clay.
125 to 145 feet, sand, clay and quicksand (water-bearing).

145 to 161 feet, clay and sand (water-bearing).
161 to 265 feet, limestone.
265 to 285 feet, soft limestone.
285 to 520 feet, limestone.
520 to 525 feet, layer of sandstone.
525 to 535 feet, shale.
535 to 595 feet, sandy shale.
595 to 890 feet, St. Peter sandstone (water-bearing).

It was originally intended to erect a steam plant for the new pumping works, but as the De Kalb Electrical Company made the city of De Kalb a favorable proposition for operating the works; and the ex-

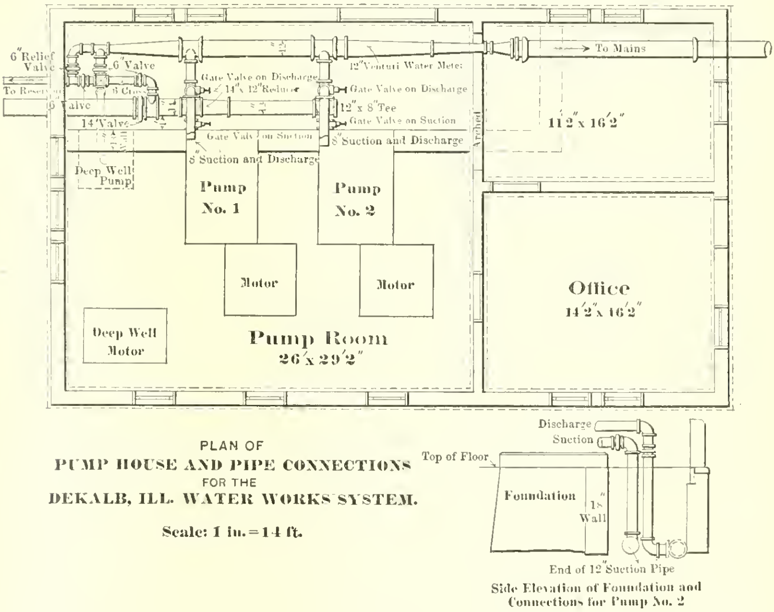


Fig. 3.

perience of the city in the management of its own works was not such as would warrant expectations of economical management in the future, it was finally decided by the City Council to contract with the De Kalb Electrical Company to do the pumping for the city for a period of ten years, and the plant was designed and built on this basis.

At the site of the well was erected an inexpensive brick pump-house, divided into a pump-room with an alcove storage-room and a small office.

Within 30 feet of the pump-house is built a storage reservoir which is also of brick, 65 feet in inside diameter, 22 feet in extreme depth and of a capacity of 500,000 gallons. A wall 2 feet in thickness and 6 feet

in height is built across the center of the reservoir, dividing it into two portions, so that water can be pumped into or out of either or both sides, and with a valve located at the further end of the cross wall. A circulation can thus be maintained and any sand pumped from the well will be deposited in the reservoir instead of in the mains. The roof is a conical truss roof, supported only at the walls. The water is to be pumped from the deep well into the reservoir by a deep-well pump of a capacity of 300 gallons per minute, run by a 25 horse-power motor. From the reservoir the water is taken by either or both of two service pumps, each of a capacity of 500 gallons per minute and each operated by a 50 horse-power motor, and forced through the mains into the stand-pipe or, in case of fire, by direct pressure into the mains. The plan of the foundations and piping (Fig. 3) will make the general arrangement plain.

At the time of completing the well, a test was made as to its capacity for furnishing water, and it was found that in pumping at the rate of 300 gallons per minute the surface of the water would descend, from its stationary position, 65 feet below the surface, to a depth of 165 feet below the surface. Consequently the deep-well pump cylinder was placed 161 feet below the surface with a 6-inch suction pipe 25 feet in length below it.

In selecting a deep-well pump for the service required much trouble was encountered in obtaining what was desired. Very little attention has apparently been given by manufacturers to developing efficient pumping machinery for raising the largest possible amount of water out of deep bore holes, and few of the manufacturers were found who would guarantee the efficiency of their pumps. Most of the pumps offered were single acting. That is, they performed practically all of the work on one-half of the revolution. And, to attain the capacity desired, this involved a large pump cylinder, and a very uneven distribution of power. It involved also considerable loss of work in raising the long and unbalanced pump-rod at each stroke. The ordinary form of deep-well valve consisting of a spherical brass ball seated in a ground brass seat and having a very limited rise, had not been found satisfactory at the old works and a better arrangement of valves was also desired. Only one of the pumps offered gave any promise of the desired results, and this was offered by the Downie Pump Company. This pump consisted of a double-acting pump-head and the Downie water cylinder and patent conical valve. The valve possessed a number of admirable features, among which may be named large water way and simplicity of construction, and it was adopted unchanged. (See Figs. 4 and 5.)

The Downie power pump-head as originally submitted, while containing the principle most satisfactory to the writer, was not satisfactory in the details of design or construction. A modified form

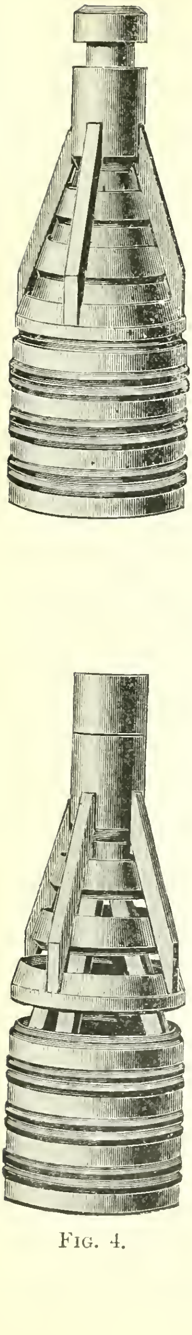


Fig. 4.

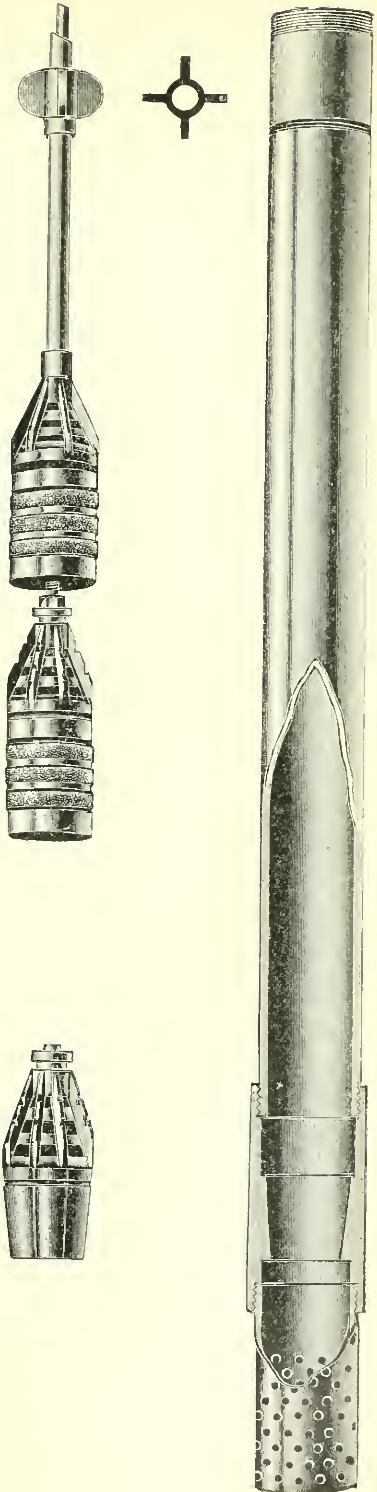


Fig 5.

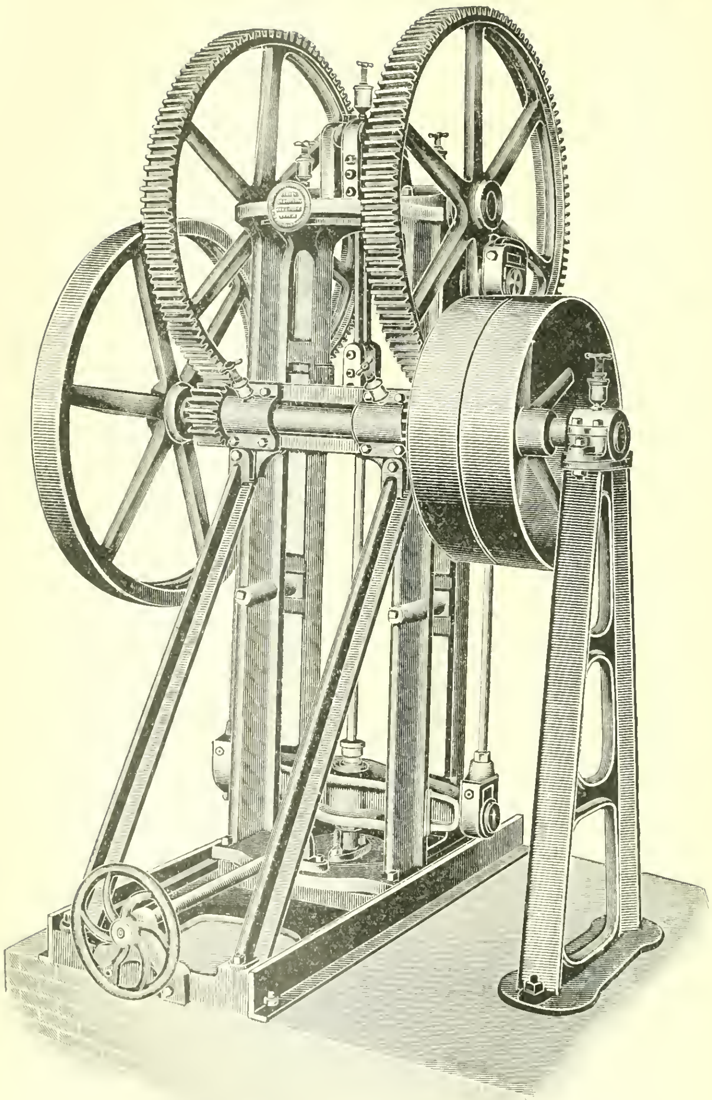


Fig. 6.

of the Downie pump was finally designed by the writer, but has not yet been constructed.* A temporary pump is now at work, while the new pump is being built by this company. This pump is expected to give an efficiency of about 65 or 70 per cent. The deep-well pump is connected to the motor by a 12-inch belt. The motors were furnished by the General Electric Company.

There are two multipolar motors of 50 horse-power each, at 200 volts, to operate the service pumps, and one multipolar motor of a capacity of 25 horse-power at 220 volts, to operate the deep-well pump.

The motor rating is on the basis of the mechanical horse-power delivered by the armature shaft at pulley or pinion of same. The field cores and frames of the motors are of cast steel.

Their armatures are of the "iron clad" type, wound with machine-formed coils, and are interchangeable and separately insulated. These coils are placed in slots in the armature punches in such a manner that should a coil become injured in any way, it may be readily replaced without disturbing the rest of the winding.

These motors are sparkless during changes varying from full load to no load, and the design is such that changes varying from full load to no load can be made without varying the position of brushes. The motors are so designed that when running at their normal load the rise in temperature in any part, above the surrounding air, will not be more than 100° Fahrenheit.

It was required that the speed of the 50 horse-power motors should not be greater than 495 revolutions per minute, at 200 volts, and the speed of the 25 horse-power motor should not be more than 565 revolutions per minute at 220 volts.

The motors have a guaranteed efficiency of not less than 90 per cent. at full load, and not less than 82 per cent. at one-half load; and were to be capable of carrying 25 per cent. over-load for a period of eight hours without injury.

These motors were designed and constructed for this particular work, and the motor of the east pump was tested for efficiency with the following results. This motor was disconnected from the pump. A split iron pulley was fastened to the shaft for use as a brake pulley, and to this a friction brake was attached. The pulley which was furnished by the city did not fit the shaft well and was therefore not perfectly true in circumference. For this reason it was impossible to make an absolute measurement of the maximum power of the motor; for at the higher

* Since writing the above, a pump, modified somewhat from the writer's design, has been furnished the city of De Kalb by the Downie Pump Co. and is now on trial. The pump is shown in Fig. 6.

powers the irregularity in the pulley rim caused the brake to become unsteady and the weight necessary to balance it could not be determined with sufficient accuracy. Enough measurements were made, however, to give data for determining the curve of efficiency of the motors, from which the efficiencies at the limits of the capacity of the motor were calculated. The following table, which represents the average of a number of measurements, shows the results obtained:

TEST OF MOTOR ON EAST PUMP, DE KALB PUMP HOUSE.

Time from	10.34	10.46	11.38	2.02
Time to	10.44	10.56	11.45	2.18
Amperes	95.4	106.5	157	16½
Volts	218.7	216	199	217¾
Watts	20864	23004	31243	3557
Electric H. P.	27.98	30.84	41.88	4.76
Revolution of motor per minute	399	396	402	379
Weight on brake arm	113	123	154	No load.
Weight of brake	35¼	35¼	35¼	
Corrected weight	77¾	87¾	118¾	
Length of brake arm	4 ft.	4 ft.	4 ft.	
Brake H. P.	23.59	26.41	36.28	
Efficiency	84.3	85.63	86.86	

From these experiments the following approximate average efficiencies under various loads were calculated:

H. P. Furnished to Motor.	Calculated Efficiency of Motor.	Guaranteed Efficiency.	H. P. Delivered to Pump.
25	83.56		20.89
30	84.81	82	25.44
35	86.16		30.15
40	87.41		34.96
45	88.66		39.90
50	89.81		45.08
55	91.06	90	50.08
60	92.31		55.39

From the data obtained it will be seen that it took 4.76 horse-power to run the empty motor; of this .75 horse-power was ascertained to be consumed in the field wires. The writer had the assistance of Mr. J. W. Glidden, Superintendent of the De Kalb Electrical Company, in the selection and arrangement of the electrical features of the plant.

The service pumps (see Figs. 7 and 8) were furnished by the Gould Manufacturing Company, of Seneca Falls, N. Y., through their Chicago office. This company also had the contract for furnishing the motors and fittings. The pumps consist of two vertical triplex single-acting power pumps, having plungers 10 inches in diameter and a stroke of 12 inches. The approximate weight of each pump is about 18,000 pounds. The connecting rods are joined to the plungers by cross heads, which are outside guided. All bearings are of phosphor bronze. The pinion shaft is of machine steel, is 3 inches in diameter and runs in two bearings

12 inches in length. The crank shaft is forged steel, the main bearings being 6 inches in diameter by $15\frac{1}{2}$ inches in length. The pumps are arranged throughout so that all parts are readily accessible and all

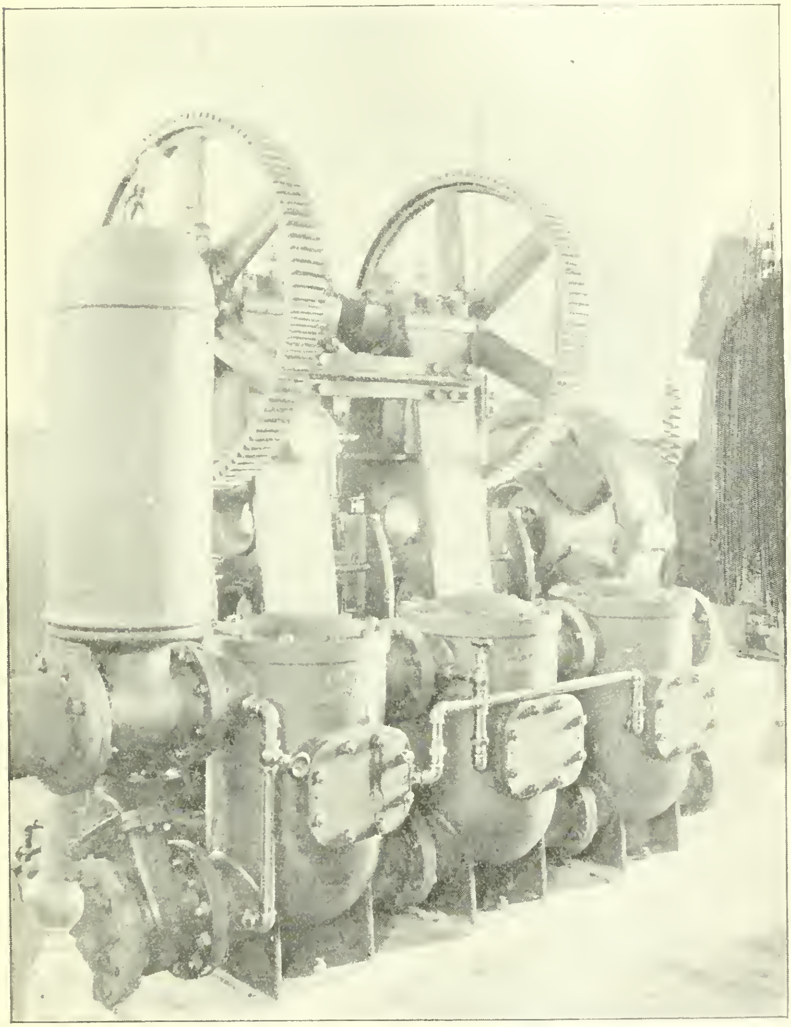


FIG. 7.—PUMP AND MOTORS, FRONT VIEW.

wearing parts can be readily taken up. The motors are coupled directly to the pinion shaft of the pumps and the speed of the motors is reduced by proportioning the pinions and gears in the ratio of one to five and

two-thirds. The gears are cut and the pinions are made of raw hide held by bronze shrouds. First-class workmanship was specified, and the Gould Company have strictly complied with the specifications and

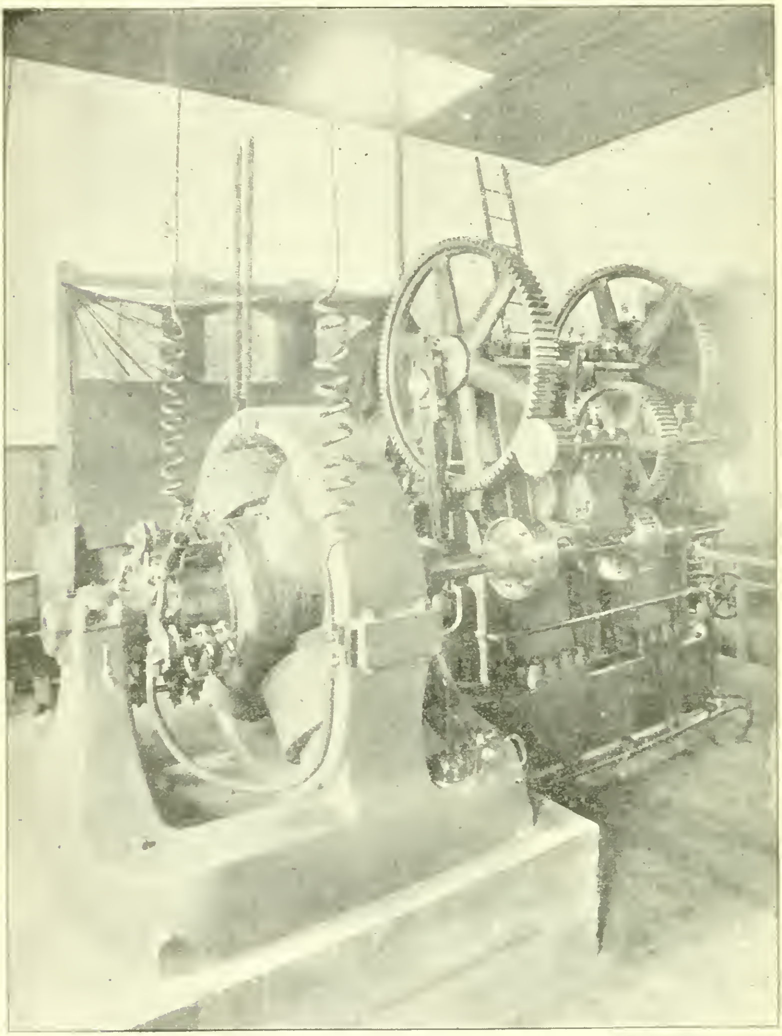


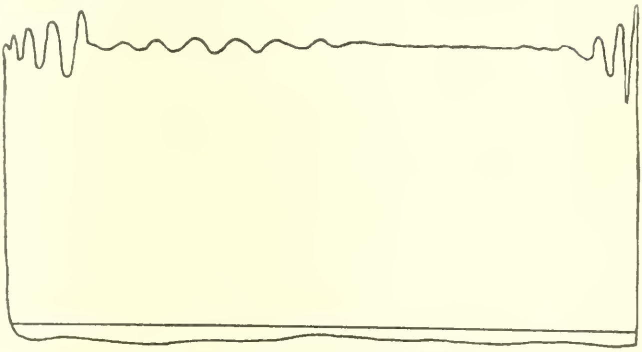
Fig. 8.—Pump and Motors, Rear View.

furnished a pair of pumps which, while solid and substantial in construction and free from vibration, are yet highly efficient. Both of the pumps were carefully tested.

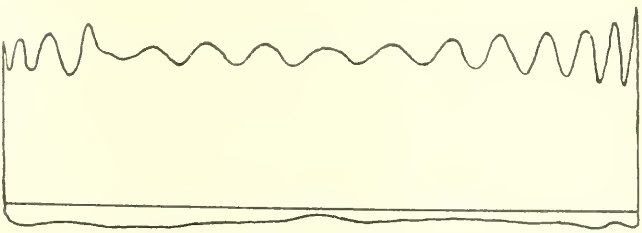
The test of the west pump was as follows:

TEST OF WEST TRIPLEX PUMP.

Time from	9.08	9.58	10.06	10.38	11.32	1.16
Time to	9.30	10.02	10.20	10.50	12.00	2.00
Amperes	27.3	130	156	206.5	215.75	243.3
Volts	217	195	193.4	195	192	186.8
Watts	8094	25350	30170	40255	41433	45455
Electric H. P. furnished	10.85	33.95	40.44	53.95	55.54	60.93
H. P. delivered by motor		29.13	36.14	49.1	50.84	56.60
Water pressure, lbs., No. load		66.5	84.5	125.5	126	129.5
Suction lift, lbs.		4	4	4	4	4
Total lift		70.5	88.5	129.5	130	133.5
Area plungers, square inch		78.54	78.54	78.54	78.54	78.54
Length of stroke, feet		1	1	1	1	1
Revolutions per minute	43.9	41.75	41.71	42.5	42.5	45.93
Effective H. P. delivered by pump, including slip		20.01	26.27	39.29	39.44	43.78
Combined efficiency of pump and motor		58.6	64.9	72.8	71.0	71.9
Efficiency of pump, including slip		68.7	72.6	80.2	77.5	77.3
Slip		2.1	2.1	2.1	2.1	2.1
Net efficiency of pump		66.6	70.5	78.1	75.4	75.2



60 pounds spring; 90 pounds pressure.



60 pounds spring; 47½ pounds pressure.

FIG. 9.—PUMP CARDS.

The efficiency under the contract was to be 75 per cent. for the pumps under full load and 68 per cent. under half load. The former was exceeded in the test. The latter was not quite reached at 66½ pounds pressure. But as the pumps were new and the packing about the pistons was tighter than necessary it was evident from the work of the pump that it could easily reach the guaranteed efficiency. This was afterward exceeded on a further test.

The pumping plant is connected with the water mains by a 12 and 10-inch force main, intersecting the old system of mains at four points. Plans were made for an additional main between the pump-house and the water mains by another circuit when the growth of the city shall require, and for reinforcing the present system of 4-inch mains with 10, 8 and 6-inch pipe in such a manner that a reasonable fire service can be obtained.

In their contract with the city of De Kalb, the De Kalb Electrical Company assume the care of the pumping machinery and agree to furnish all oil and waste and all fuel needed to keep the engine house warm in winter. They also made the connection between the motors and their power-house, which was done by two circuits leaving the pump-house in different directions in order to provide against accident to the service line. They further agree to make all repairs on the machinery free of expense for labor, the city to furnish the material for the repairs. The General Electric Company have guaranteed that the repairs on the electrical machinery shall not exceed 2 per cent. per annum during the first five years.

Regarding the service to be furnished the De Kalb Electrical Company agree to maintain a minimum depth of 15 feet of water in the reservoir at all times and a minimum height of 55 feet of water in the standpipe with a daily average of at least 65 feet. They are to receive as compensation for pumping the water from the well into the standpipe 4 cents for each 1,000 gallons pumped. The average standpipe head pumped against is about 62½ pounds pressure per square inch. The De Kalb Electrical Company are also to furnish water for fires under any pressure required by the city not to exceed 125 pounds per square inch at the pumps, for which service no extra compensation is allowed. When fire pressure is desired the standpipe will be closed by a Dousman automatic pressure retaining valve, which is so arranged that by increasing the velocity of water into the standpipe the valve closes automatically and the pressure can then be raised as desired. When the pressure is again reduced the check valve opens and the standpipe is again brought into service. This valve also closes when the water in the standpipe reaches a certain elevation, in this way preventing overflow.

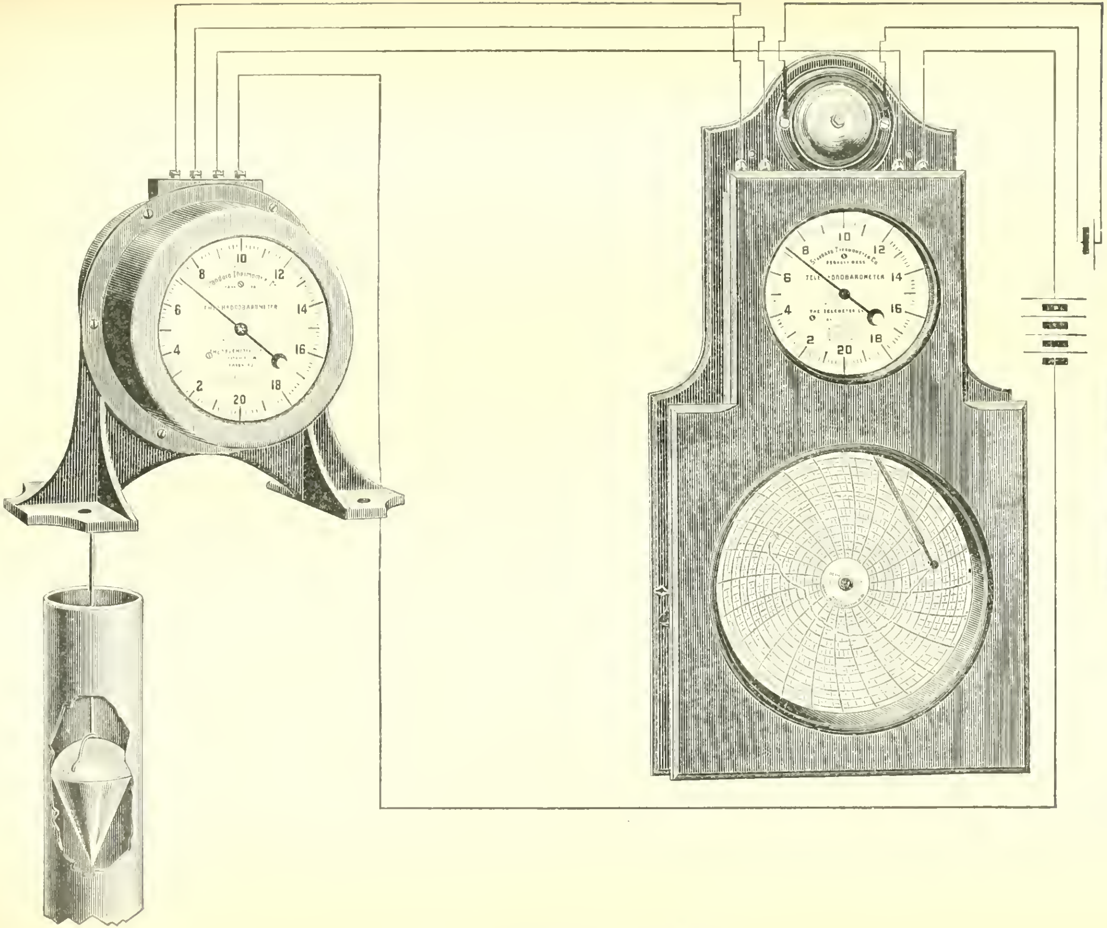


Fig. 11.—Tele-hydro-barometer.

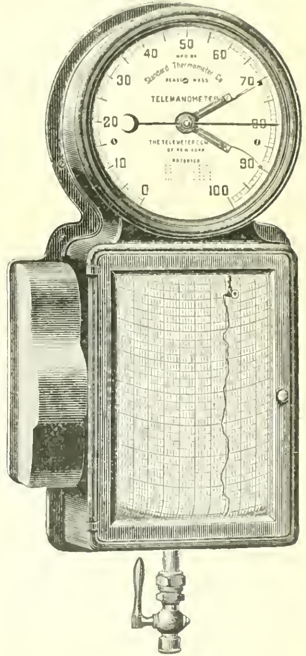


Fig. 10.
Recording Pressure Gauge.

The desired fire pressure is determined by setting the relief valve at the pump-house and when the pressure exceeds the desired amount the relief valve opens and the water passes back into the reservoir, thus preventing accidents by overstraining the mains. Accidents due to starting the pumps with the discharge valves closed are prevented by the use of fusible plugs at the power station. These plugs burn out before damage can be done to the motor, should the current become too strong.

The lack of available information concerning many points of importance in the design of the new work and the extension of the system, and the necessity of systematic records, became very obvious when investigating the De Kalb water works.

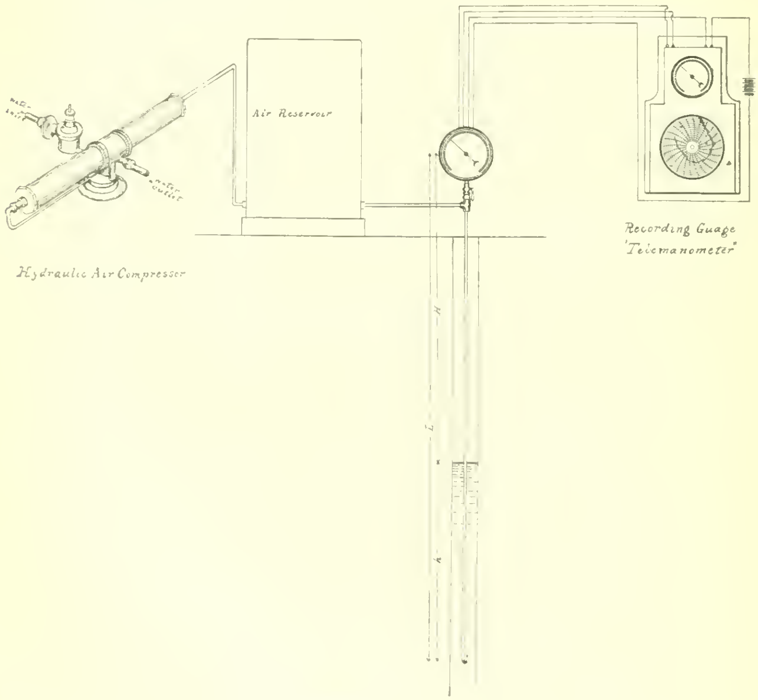


Fig. 12.—Deep Well Gauge.

The agreement with the De Kalb Electrical Company also rendered it important that systematic and automatic records should be kept in order that the manner of carrying out the agreement should be known beyond question. This was important for the protection of the company as well as for the city itself. For these reasons a number of recording devices were introduced into the system and made a feature of the works.

To measure the amount of water pumped, counters were attached to each pump. For the deep-well pump this furnishes, with the known capacity of the reservoir, a check on the slip of the deep-well pump valves. For measuring the water pumped into the mains, besides the pump counters, a 12-inch Venturi meter was purchased of the Builders' Iron Foundry of Providence, R. I. (see Fig. 13). This meter is provided with an automatic register which records the water pumped in cubic feet (see Fig. 14). The counters on the service pumps furnish a check on this meter. It was intended to secure a graphical record of the hourly, daily, weekly and monthly variation in the consumption of water, but, although the manufacturers were considering a recording device of this kind, they had not perfected the same, and were unable to furnish such a device.

To keep a record of the height of water in the standpipe and the pressure carried at all times, including fire pressures, a recording pressure gauge (see Fig. 10) was placed in the City Clerk's office, and attached to the main by a suitable connection. This pressure gauge was furnished by the Standard Thermometer Company, and includes both an ordinary dial gauge and a graphical recording apparatus. To keep a record of the height of water in the reservoir a gauge, called a tele-hydro-barometer, was purchased from the same company (see Fig. 11). The general principle of this gauge is easily understood from the illustration. The elevation of the float is shown on the dial at the reservoir, and is also shown both by dial and by a graphical record on the recording device which is also located in the office of the City Clerk.

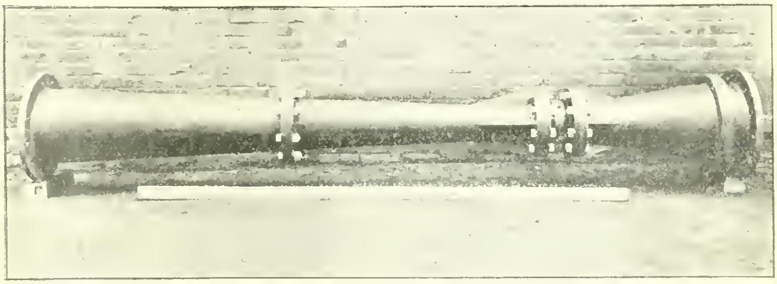


Fig. 13.—Venturi Meter.

Before drilling the last deep well at De Kalb, which is now used for the new public supply, an attempt was made to secure data concerning the various artesian wells which had been previously drilled in that city. No data on which reliance could be placed could be obtained. It is known by those who have paid attention to deep and artesian wells that

there is a change of level in the waters of these wells which has often a serious effect on their utility. In some cases this is caused by the sinking of new wells, or the abandonment of old ones. In others by the gradual filling up of the wells by sand, etc., or by the opening of the pores of the rock by solution. It is also believed that there is a seasonal variation in the flow of wells, and other variations due to barometric pressure. No extended series of observations have been made on these subjects, and had they been made at any one place they would still be inapplicable, except in a general way, to the locality under consideration.

One clause of the contract with the DeKalb Electrical Company provided that they should not be required, either at the present works or at any new works which should be built, to lift water with the deep-well pump more than 175 feet from below the surface. All of these considerations, together with the certainty of the necessity of the ultimate enlargement of the plant, rendered it desirable that detailed information be secured concerning the new artesian well.

The writer provided, in the specifications for deep-well pumping machinery, that a deep-well gauge, either on a plan proposed on drawings furnished, or on some other approved plan, should be provided. Mr. E. E. Johnson, M.E., Mem. Wes. Soc. Eng., offered the best suggestions for such a gauge. Mr. Johnson's suggestions were that by means of a small air compressor attached to the deep-well pump, air should be slowly forced through a small pipe running down the well to at least as low a point as the bottom of the pump cylinder. The pressure required to displace the water in this small pipe could then be measured by a pressure guage, and the length of the air pipe being known, the depth of water above the base of the pipe would be shown by the guage, which could be graduated, if desired, so that it would read directly in feet below the surface. The only objection to this was that no record could be kept when the deep-well pump was not running, and it was desirable to use some other motor beside the pump itself to operate the air compressor. Mr. L. B. Merriam, Mem. Wes. Soc. Eng., who superintended the construction of the plant as herein described, and whose efficient work was greatly appreciated, suggested that a Bishop & Babcock hydraulic air compressor be used for this purpose. This suggestion was also adopted. This compressor furnishes all the air necessary at a small expense for water, using about 500 gallons per day.

To make a permanent record of the well gauge readings, a telemanometer was purchased, the recording device of which is to be placed in the City Clerk's office (see Fig. 12). The recording pressure gauge and the deep-well gauge revolve once per day, and the cards have to be removed, dated and filed daily. The reservoir gauge revolves once in

seven days, as the variations are slight and the record for short times not as important.

From an economical standpoint the immediate saving in expense

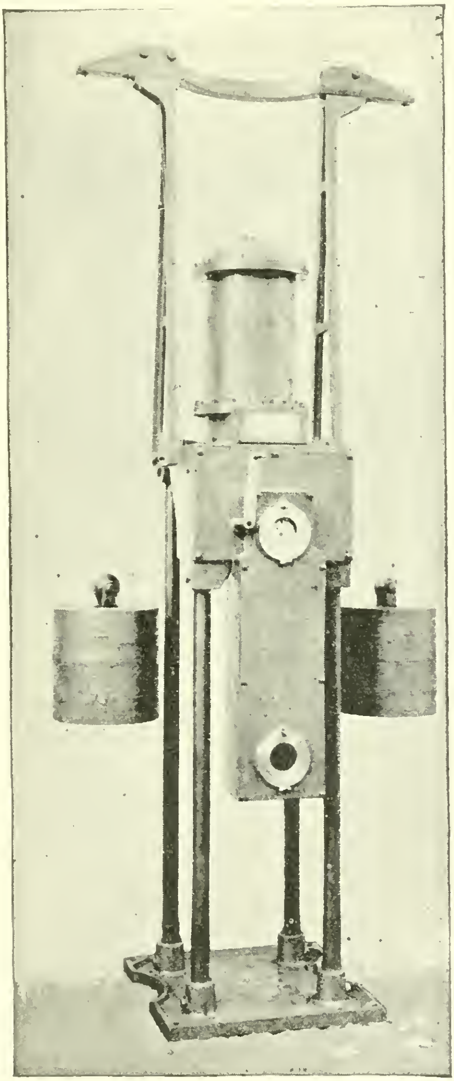


FIG. 14.—REGISTERING APPARATUS FOR VENTURI METER.

to the city of De Kalb by the construction of the new plant is obvious, as the difference between 10.8 cents per 1,000 gallons, the expense of pumping during the year 1893-94, and the present contract price of 4 cts. per 1000 gallons speaks for itself.

The economy of pumping in the way herein described, where large amounts of water are to be used and economical management is attainable, is, however, more than doubtful. This can be readily understood by tracing the loss of power through the system. Neglecting the matter of deep-well pumping, the loss in domestic pumping is as follows: There is first a loss of about 10 per cent. at the dynamo; an additional loss of 10 per cent. in the transmission of power from the dynamo to the motors; a loss of 16 per cent. through the motors and a loss of 32 per cent. in the pumps. This gives a net efficiency of the plant for domestic service from the power developed in the engine of only 46.27 per cent. The efficiency for fire service is, however, about 55.28 per cent., but fire service of course constitutes a very small amount of the pumping. With a steam engine equal in economy to that operated by the De Kalb Electrical Company, and the same class of pumps, but proportioned for the domestic work, the loss would be not more than 25 per cent.; the efficiency of the plant from the power developed by the engine in this case being 75 per cent. In this case a pump for fire purposes would need to be held in reserve.

The advantage the Electrical Company has over a municipal power plant is in the greater economy of the larger power plant and in the advantage to be derived from good business management as compared with the ordinary municipal management. The principal advantage is, however, that they can do the necessary pumping at such times as their other business is at a minimum, and they pay nothing extra for the services of engineer and fireman, and the incidental cost of operating the power plant. The proportional extra cost of coal is probably not as large as the proportional increase in power furnished; for the numerous losses incidental to the operation of a power plant must occur in any event and are not largely increased by the additional power developed.

The writer's estimate for pumping 200,000 gallons per day with a steam pumping plant, with good management, was, including all expenses, \$5.71 per day, against the contract price of \$8.00 per day for the same amount pumped. With a greater consumption, the difference would be greater; with a smaller consumption the difference would be less, and with a consumption of 150,000 gallons or less the difference would be in favor of the electrical plant. The average consumption of water for the last three months has been but little over 100,000 gallons per day. There will doubtless be a rapid gain in consumers, however, with efficient service and a constant supply.

The value of any system and method is relative only. A system which is economical under one set of conditions, may be the reverse where the conditions radically differ. It is only by practical illustrations that the economy of any particular system can be fully developed

and thoroughly understood. As a practical illustration of the application of electricity to the municipal water-works service, it is believed that the De Kalb plant will not be without interest.

DISCUSSION.

After reading the paper, Mr. Mead exhibited a number of illustrations by means of stereopticon views, with explanations, as follows:

The map and sections (Fig. 1) illustrates the geological conditions in the Upper Mississippi Valley and the relation of the water-bearing strata. The St. Peter sandstone is the source of supply for the city of De Kalb as well as for a number of other cities, shown on the map. There are also a large number of deep and artesian wells in Chicago that are drilled into both the St. Peter and Potsdam sandstones. The more shallow wells are into the St. Peter sandstone and the deeper wells reach the Potsdam sandstone. The sections at the bottom of the map show the relative vertical positions of the St. Peter and Potsdam sandstone. Lying just above the Potsdam sandstone is about 150 feet of the lower magnesian limestone, which furnishes an impervious cover and to a considerable extent confines the water in the pervious sandstone. On top of the magnesian limestone lies the St. Peter sandstone, which is throughout Northern Illinois about two hundred feet thick. Both of these deposits, the Potsdam and St. Peter, are sandstones which allow the free passage of water. The water probably also very largely passes through fissures in the rock as well as through the rock material itself.

The north and south section is on a line passing near the position of De Kalb. The water from the St. Peter sandstone at De Kalb is found to be higher than the water from the St. Peter at Rockford, which is unusual, as De Kalb is considerably further south, and the hydraulic grade of these waters usually descends toward the south. This fact would show that the water at De Kalb really comes from a point considerably further north than that at Rockford, and at a consequent greater altitude. There is an out-crop of the St. Peter sandstone at Dixon, Ill., along the Rock River, and also at Ottawa, Ill., along the Fox River. Ottawa is built practically on the St. Peter sandstone.

Fig. 2 shows the relative location of various features of the De Kalb water-works system. The Kishwaukee River is just to the west of the pump-house and reservoir. It is dry most all the season. The main reason for locating the plant at this point was in order to get a switch for the delivery of coal, as it was originally intended to erect a steam plant. This location is also one of the lowest points in the city It was originally expected that we should be able to reach the water without the use of a deep-well pump, by sinking a shaft, but the water did not rise as high as was expected, and this idea had to be abandoned.

Ths reservoir, which is located just west of the pump-house, will hold a half million gallons of water.

The electric power plant is shown at the east end of the map. One line of wire follows the railroad down to the pump-house; the other follows the streets, so that they have two separate lines in case of accident. The point where the standpipe and the old pump-house are located is about the highest point in town.

A 12-inch main was laid to join the old pipe system. A 10-inch pipe connects the 12-inch with the system at several points. There is also a 10-inch pipe running from the old pump-house to the standpipe, but the pipe joining the two 10-inch pipes is at present 6 inches. This will be changed as soon as the finances of the city will permit.

Fig. 3 gives a general view of the interior arrangement of pump-house, and the location of the well, the deep-well pump, the service pumps and the motors. The water is raised by the deep-well pump and forced through a 6-inch pipe into the reservoir. The valves are so arranged that it is possible to pump into the mains with the deep-well pump if it becomes necessary, or to pump directly into the suction of the service pumps, if for any reason it becomes necessary to fix the reservoir. The service pumps, of a capacity of 500 gallons per minute each, are located as shown in the figure. The Venturi meter is also located in the pump-house at the point shown. No test was made of the Venturi meter, but allowing for the slip of the pumps, the meter and the pump counters were found to agree very closely. The pumps are positive in motion, and so that the counter measured exactly the amount of water pumped, plus the slip of the valves. The Venturi register is located just above the meter in the pump-room, and records the amount of water in cubic feet.

In Figs. 4 and 5 the deep well cylinder and valve that are used at De Kalb are shown. The illustration shows the valve both closed and open, and shows very plainly its action. When open, the valve gives almost a straight water way and closes very closely, giving very little slip. The double-acting pump cylinder is also shown in the cuts. The rod of the upper valve is hollow, and the rod of the lower valve passes through it. These rods are actuated by a pump-head in which the eccentrics are placed opposite each other, or at an angle of 180 degrees, so that when one rod is going down the other is raising. The rods are arranged to balance each other in weight, so that there is less loss in the action of the pump than in a single-acting pump. See Fig. 6.

Fig. 7 gives a front view of one of the service pumps and motors. Fig. 8 gives a rear view of the same. Fig. 8 shows the motor nearest the observer, and of course the size of the motor appears much larger relatively than it really is. The direct coupling between the motor and

pump is quite clearly shown in the illustration. The pinions that run the main gear, as well as the pinion on the motor shaft, are raw-hide; the others are cut-gears.

Fig. 9 shows two pump cards taken from one of the cylinders on one of the service pumps. One is taken while the pump was working against 90 pounds pressure; the other while the pump was working against about 47½ pounds pressure. The horizontal lines in the illustrations are the atmospheric lines.

Fig. 10 is a view of the recording pressure gauge, which is attached directly to the main and is located in the City Clerk's office. The card is removed and replaced every day, and in this way a record is kept of the pressure at all times, including, of course, during fires. The height of water in the standpipe is also shown by this gauge. This gauge protects both the city and the electric company, for with its evidence no unjust claim can be sustained as to what pressure they had or did not have at any particular time.

Fig. 11 illustrates the tele-hydro-barometer. This, as well as the recording pressure gauge, was made by the Standard Thermometer Company. The float is placed in the reservoir and marks the depth of the water. This depth is shown on the gauge above the float and also on the recording device, which is located in the office of the City Clerk. This record will show whether the Electrical Company are complying fully with their contract in keeping a sufficient amount of water in the reservoir.

Fig. 12 is a diagram of the deep-well gauge. On the right is shown a Bishop & Babcock hydraulic air compressor. The air passes from this into the air reservoir and thence into the small pipe, which runs into the deep well. Just enough air is furnished to keep it bubbling slightly from the bottom of the pipe, and the amount that the water is depressed is shown by the pressure on the gauge at the top of the pipe. From this pressure the distance from the floor to the water surface can be calculated by the formulæ. $H = L - h$, where L equals the distance from the center of gauge to bottom of air pipe, h equals gauge reading in feet, and H equals distance from center of gauge to the surface of the water. The fluctuations in the surface elevation of the water can in this way be ascertained. To record the fluctuations, a tele-manometer recording gauge is used, which will also be placed in the City Clerk's office with the other gauges. This gauge will give a record of the well variations at all times during the day and night, and it is hoped that in this way some valuable information concerning the seasonal and other variations in the water of artesian wells can be ascertained. This, it is believed, will be of the greatest advantage if at any time it is desired to extend the system.

Figs. 13 and 14 give views of the Venturi meter and register.

The President.—The 22 per cent. difference in the efficiency between motors and steam plants suggested is a little startling. The question would naturally arise, unless electric motors are somewhat of a plaything, why the city of De Kalb, in trying to pump water, did not use the steam plant. It certainly would cost less. Am I right in that conclusion?

Mr. Mead.—The question of ultimate economy is not one of efficiency alone, but of attendance as well. The De Kalb Electrical Company need no extra men on account of the extra power furnished the city for pumping, but are doing the work with the same force with which they ran their plant before contracting with the city. If a steam plant were used by the city for pumping, attendance would have to be provided, and this cost would have to be added to the cost of operating the plant. Besides this, the type and the size of the engine used would make considerable difference in cost of operation, while it would not make any difference in the efficiency of the two types of pumping plants mentioned. I have based my estimate of efficiency on the power generated by the engine, and the type of engine used would therefore not modify my estimate, while it would modify the cost of pumping to a large extent. Different types and sizes of engines use all the way from 12 pounds of steam per horse-power per hour up to perhaps as high as 100 pounds of steam per horse-power per hour, and the use of an inefficient engine and the extra cost of attendance might make the more efficient pumping plant much more expensive to operate.

The President.—Well, to follow up the thought: was there anything preventing the placing of the power plant of the Electric Company adjacent to the pumping plant, so that they might transfer the power of the large engine direct to the pumps?

Mr. Mead.—No and yes. The original idea was to build a steam plant. It was expected at the time when the well was first drilled that a steam pumping plant, to be operated by the city itself, would be used. The well was drilled, therefore, in its present location on account of its being the lowest point in the city, and also being adjacent to the railroad. For this reason this position of the plant was fixed. Afterwards the Electrical Company made a proposition to the city to operate the plant by electricity, which was finally accepted by the City Council. My estimates were that, on 200,000 gallons of water per day, which amount we expect the city of De Kalb will use, the cost will be, including cost of attendance, about \$5.75 per day. Under the contract with the Electrical Company, the cost of pumping 200,000 gallons per day will be about \$8 per day. The difference in the cost per diem between the two methods of pumping will grow much larger as the amount of

water increases. If, on the other hand, as is just now the case, the amount of water pumped is 100,000 gallons per day or less, the city could not have pumped this amount as cheaply per 1,000 gallons with the proposed steam plant as the De Kalb Electric Company will pump it for them with the present electrical plant.

The President.—The question in my mind was about this Electrical Power Company.

Mr. Mead.—To explain further, the city was to construct their own pumping plant The De Kalb Electrical Company desired to do the work of pumping. Now, they could have done it cheaper, I have no doubt, if they could have coupled their engine directly to the pumps. This, however, would have been impossible even if the well had been adjacent to the power station. The De Kalb Electrical Company are furnishing power and light. They are obliged to run their plant in any event, and although the efficiency of the arrangement is low, the cost of operating the pumps is very small, as nothing extra is paid by them for attendance. They are, in fact, utilizing what may almost be considered waste power.

Mr. Johnson.—Coming in late, I missed part of Mr. Mead's paper. I should like to ask the gentleman if he stated the combined efficiency of the plant and the efficiency of both the motors and pumps?

Mr. Mead.—I gave the combined efficiency of the plant as about 47 per cent.

Mr. Johnson.—Do I understand that that is the efficiency of the electrical motor and pump combined?

Mr. Mead.—That is the efficiency of the plant from the De Kalb Electrical Company's engine clear through the pump. It is the power actually utilized after deducting the loss in generating the electrical current, the loss in transmitting it from the dynamo to the motor, the loss in conducting it through the motor and changing it into power, and the loss in the pump itself. The loss in the pump, as I have explained in the paper, is greater on domestic service than it would be on the fire service. The pump is designed for fire service. With the same pump designed for domestic service, that is, a pump of the same general class, but designed for 60 pounds instead of for 125 pounds service, we should probably get an efficiency of 75 per cent. in a test. These pumps showed an efficiency in one test, on a full load, of 78 per cent. The motor under half load showed an efficiency of 84 per cent., then under full load it showed an efficiency of 91. I was simply stating the fact that under domestic pressure the efficiency of the plant from the engine through the pumps was about 47 per cent. While with the engines at the pump-house, and with the same pump attached directly to it, an efficiency of from 70 to 75 per cent. of the

power of the engine could be obtained. The Electric Company simply have the advantage of having a larger steam plant, which is probably of a better type than the city would purchase, and they have the further advantage that their plant is managed on business principles. They have the disadvantage of the difference in efficiency.

Mr. Johnson.—May I ask further if you have data for the efficiency of the engine and the generator, so that you could get the presumed loss of the generator?

Mr. Mead.—The loss in generating the electrical current was estimated, and was not from any experiments or tests that I made myself. I think the Electrical Company have determined that they can obtain 90 per cent. efficiency from their generators.

I made no test of the deep-well pump, as the deep-well pump at present is a temporary one. I believe, however, Mr. Merriam has made some preliminary tests on the present plant and I think he can give us some data.

Mr. Merriam.—I do not believe I can add very much to what Mr. Mead has said, with the exception that we did make an approximate test to-day on the efficency of the deep-well pump. We found the efficiency of the pump itself to be about 60 per cent. I think this is very high for the work it is doing, that is, it was lifting about 200 gallons of water a minute a height of 110 feet. By previous experiments we know there was very little slip in the pump. We ascertained the slip by taking careful measurements of the reservoir and compared the water pumped with the number of strokes of the pump. I have seen several experiments with the ordinary steam head on deep-well pumps, and I found that we only obtained about 45 to perhaps an extreme of 55 per cent. with the very best of designs.

The President.—On the question of the deep-well pump I have had a little experience, and I would like to make an inquiry as to what success is obtained in connection with these rods, one running inside the other. How often they have failed, if at all?

Mr. Mead.—I cannot speak from experience at De Kalb. The pump at that place has only been in use for a few months. At Monmouth, Ill., one of the direct double-acting steam-heads has been in use for something over three years, and the Superintendent of Water Works tells me that they have had very little trouble. I don't think that they have had a breakage once in six months. At De Kalb there have been one or two breakages, which I think are due perhaps to the fact that the well is not perfectly straight.

The President.—Will you tell us what size these rods are?

Mr. Merriam.—The outside rods are an inch and a half in inside diameter, I think, and the inside rod is an inch and an eighth in diameter.

Mr. Mead.—The inside rod is a solid steel rod. The outside rod is inch and a half steel pipe. The breakage always occurs in the outside rod where the thread is cut, which is of course the weakest point. In the new design for the rods which I have proposed, the outside rods are to be made of wrought-iron pipe, upset at the ends so that the outside rod will be as strong at the coupling as at any other point.

The President.—I would like to know what the city of De Kalb spent in getting this plant in working order, and I would like to know further the saving to the city in the amount of water they are pumping?

Mr. Mead.—The total cost of the plant was about as follows:

Ground for pump-house and reservoir	$ 425 00
Cost of well	2,100 00
Reservoir	6,700 00
Pump-house	2,550 00
Pumps and motors	7,000 00
Venturi meter	600 00
Water mains laid	6,500 00
Miscellaneous costs, including engineering and supervision	2,000 00
Total	$27,875 00

The cost of pumping into the standpipe was about 11 cents a thousand gallons before the new works were constructed. The cost of pumping under the contract is 4 cents a thousand gallons. Concerning the new arrangement, the City Clerk in his annual report writes as follows:

"With this report I have prepared the table giving the daily average of each of the nine months (under the old system) of the number of gallons of water pumped, also daily cost of engineer, coal, supplies and total cost per day. Also daily revenue from water tax collections, and the excess of costs over and above the water revenue. To save time I will give you the daily estimate for the whole term of nine months:

No. gallons water pumped	87,500	
Cost of engineer		$4 21
Cost of coal		7 26
Cost of supplies		1 06
Total cost per day		$12 53
Daily revenue from water tax		7 93
Cost over and above revenue per day		$4 60

or $1,679 per year.

"Under the new system of water works for the months of February, March and April, the daily average of water pumped is 100,481 gallons;

cost per day, $4.02; the daily revenue from water-tax is $7.93, bringing in a gain to the city over and above expenses of $3.91 per day, or $1,427.15 per year.

"This present revenue, with interest, will be sufficient to pay off all of our bonded indebtedness by the year 1909."

From this it will be seen that for the nine months for which this report (which has just been received) is made out, the cost of pumping has been over 14 cents per thousand gallons pumped.

Mr. Merriam.—It seems that this matter of small municipal pump plants is one that should be of considerable interest to all of us. These plants have heretofore been put in about in this way: A contract is made, and a standpipe is put up; and a pump, a double-acting duplex, or some ordinary type, is put in. No particular regard has been paid to the efficiency of the outfit because it is small, and it is thought to be too small to pay any attention to its efficiency. It is thought it is all right if it is a pump and pumps water. Now, it seems to me that Mr. Mead has attacked this problem in the right way. Although the plant is a small one, he has paid considerable attention to the most economical and efficient arrangement possible under the circumstances. And I think this idea is worthy of being followed out in the design and construction of all pumping plants, even if they are small.

I want to make one further remark about this efficiency of the engineering work in this particular case. The city of De Kalb had spent, before Mr. Mead was called there, about $65,000 in a waterworks plant. The mains were very largely of 4-inch pipe. They had, however, a very good standpipe, and they had a pump and three deep wells. The city paid out $3,700 per annum for the last year's pumping, and they received about $2,700. Now it appears, from the present prospect, that it will cost the city about $1,400 or $1,500 to do their pumping. Their income will be the same, $2,700. The entire expenditure for the new works is about $30,000. The interest on this entire expenditure will be saved, and in addition to that there will be a small profit inside of the receipts, as against $2,000 loss on the previously existing pumping plant.

Now, I think, as I said before, that this plant has been attacked from the right point of view. There has been an attempt to obtain the very best results, and, I think, there are a good many of these small towns—five, six, or seven thousand inhabitants—that are worthy of our best thought in that manner. I think the more we discuss these small plants the better we will be off, because I think we will learn actually more from the discussion of small plants than of the large plants that only a few of us at best will ever get a chance to design, because there are too few of them that are being built.

I wish to say further concerning the De Kalb plant that if the well were moved to the power-plant, and it was still run by the Electric Company, it would have to be run through shafting, that is, it could not be attached direct to the engine. If it were attached to the shaft they could hardly get along with a less loss than at present, for they would have three pumps attached to the shaft, which would be a long, heavy shaft, or they would have a shaft and two or three counter shafts. Now, I do not think that there would be any gain in this method; I think there would be at least 10 per cent. loss in that shaft, so that the only remaining loss we have is the transmission of the power. If the pumps were attached to independent engines, each of which was intended for pumping alone, there would be two 50 horse-power engines and one 25 horse-power engine, and it would be pretty hard to obtain anything near the efficiency that the De Kalb Electric Company obtains with the compound engine of 125 horse-power. I am very much in doubt with regard to the possibility of running the plant with any greater efficiency, even assuming the 200,000 gallons per day, especially by a city. You know the appointees of a city are generally put there more or less by politics or favoritism, and such help is, as a rule, incompetent.

When the old De Kalb pumping plant was in use they had a steam-head on their deep-well pump. I put two gauges on the pump-head and I found out that, on the up-stroke, they actually had a ten pound cushion against their work; well, it wouldn't take very many ten-pound cushions to do away with the entire efficiency.

The President.—I would like to ask in connection with the steam-head on deep-well pump working against a certain per cent. of back pressure, if it was making half the stroke it was presumed to.

Mr. Merriam.—It was making about a three-quarter stroke.

The President.—Well, it was doing very well.

Mr. Mead.—One point concerning the efficiency of this plant it would be well to bear in mind. The De Kalb Electric Company are using the water tube boilers, a good grade of engine, and it is probable that the economy of their steam plant is very fair, and that the steam plant is run under very fair conditions.

Now if, for instance, their engines are run with 20 pounds of steam per horse-power per hour, and if the city should have a steam plant, and should generate steam as economically as the De Kalb Electric Company, but should use a lower grade engine which would take 40 pounds of steam per horse-power per hour; under these conditions you will see that 20 pounds of steam in the Electrical Company's engine would practically do the same work, with even a loss of 50 per cent. in efficiency, at the same expense for coal as in the case of the city plant of lower

grade; all of which is due to a difference in the class of the machinery used.

I believed in the first place, and still believe, that a steam plant would give better results for the city of De Kalb than can be obtained by the plant as built, provided they could and would obtain a reasonably good steam engineer to manage the plant. Their experience in the past would not perhaps warrant one in drawing such conclusions, but it is a fact that, with reasonably good management and reasonable economy in the machinery, better results than are now being obtained might be expected. I made a careful estimate and calculated the cost of the 200,000 gallons of water a day at about $5.71, as against the $8 actual cost at present. This estimate was based on facts as we find them in other places, and I think this could be easily reached by reasonably good economy in the plant proposed. However, this plan was not adopted, but the city decided to try the electrical plant, which certainly largely reduced the previous cost of pumping, and is also at present more economical than the steam plant would be. For the city is not at present using more than 100,000 gallons per day. In the long run, however, and long before the contract with the Electrical Company expires, I believe a plant operated by the city would prove far more advantageous to the city of De Kalb.

Concerning the pumping plants of the smaller cities and towns I wish to say one word further. In the larger plants great attention is paid to having engines which will give a high efficiency. It has appeared to me that in the small plants the question of efficiency is also a very important point. The original cost and the running expense of these small plants are usually higher per capita than in the larger cities. The same attention to economy therefore should be paid to the smaller plants as to the larger ones, at least as far as possible. This is not ordinarily done in selecting small pumping machinery. Neither do the manufacturers seem to give it any attention. The idea seems to be considered by the manufacturers not of importance enough to give it a moment's thought. The reason for this is of course obvious. There is not enough money in the small machinery to pay for the extra work, or for the designing of the higher grade machinery. Neither is the designing engineer paid enough ordinarily to warrant him in giving great attention to securing high-grade machinery, and as there has been no demand for this class of machinery there is therefore no supply, and will not be until the engineers and the public require it. But is it not equally as essential in a small way? Is it not proportionately as essential to have economically designed machines in the small works as in the larger plants?

Mr. Cooley.—It occurs to me that, as an offset to a separate en-

gine, you could put on a separate condenser that will heat the water in the well about 4 or 5 degrees.

A MEMBER.—That same idea of temperature in the water had occurred to me when Mr. Mead was speaking of the deep-well gauge. I think the difference in the temperature of the water would make a difference in the reading of the gauge. I did not hear anybody speak about measuring the temperature of the water.

MR. MEAD.—The water in artesian wells is about uniform throughout the year. It may vary a few degrees perhaps, but as it is coming from 800 feet below the surface it preserves quite a uniform temperature. It is comparatively warm in winter and cold in summer. Most of the wells through Northern Illinois run perhaps from about 54 degrees to, in some extreme cases, as high as 60; about 54 to 55, I think, is the average of the most of the artesian wells. Variations in temperature of an individual well would be very small, and would therefore make little difference with the deep-well gauge.

A MEMBER.—In connection with the temperature of the artesian well water, I would mention one point, and the experience may be somewhat useful to you, gentlemen. At Waukegan, there is an intake pipe running out into Lake Michigan. They had trouble with anchor ice, and to get rid of the anchor ice they turned the water from an artesian well into their intake pipe and flushed the anchor ice out. That part of it was a success. But the difference in temperature of the water caused an expansion of the pipes, so that they separated at the joints and they had to connect them up.

MR. WARD.—Speaking of the pressure in artesian wells, I will say that in Marseilles we have something like 200 wells drawing all from the St. Peter's sandstone, and the water rises to the surface and flows at the surface. We have noticed there that the height decreases at the rate of from 4 to 5 inches a year. There is a regular decrease apparently in the height. There is one well there that, when I first drilled it, about 1884 or 1885, flowed about 3 or 4 feet above the surface. This is on rather high ground, and when the head was lowest, so that it began to flow merely to the surface, I noticed that there were times in which it would not flow at all, while at other times it would flow quite remarkably; sometimes it would cease entirely. The St. Peter's sandstone in that region comes to the surface at Ottawa. They use it to manufacture glass there. It outcrops along the Vermillion River and up the Fox River, and the dip is about 11½ feet per mile to north and east, so that we have to go down at some places 108 or 109 feet to reach it. The water evidently comes from Wisconsin, near Janesville. I think that at Marseilles, and along near Ottawa and just below Ottawa, and along the Fox River, there are large

springs of this same water that rush out from the rock. Some of these springs, like the one up near Dayton, just north of Ottawa, are very large. This one is probably over six feet wide and perhaps four to five inches deep, a constant stream running into the Fox River. There is another one something like that just below.

Mr. Roney.—I am informed that Mr. Mead has made a thorough and exhaustive test of a very interesting gasoline engine pumping plant, which he built at Dundee, Ill. I hope that Mr. Mead will favor us with a paper describing that plant and his very extended tests of it.

The President.—That is a suggestion that I endorse with all my heart. I think it might be well that these gentlemen, who have been raising critical questions concerning the question of efficiency of the De Kalb water works, express themselves emphatically that they do not see any bad business policy in getting water pumped for 4 cents a thousand gallons that has previously cost the city of De Kalb 11 cents.

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STOPPING A TROUBLESOME SLIDE AT A SUMMIT TUNNEL.

BY JOHN D. ISAACS, MEMBER OF THE TECHNICAL SOCIETY OF THE PACIFIC COAST.

[Read before the Society, April 5, 1895.*]

INTRODUCTORY.

PROBABLY no section of California within easy reach of San Francisco presents greater attractions than that portion of the Santa Cruz Mountains lying contiguous to the Santa Cruz Division of the Southern Pacific Railroad (commonly called the Narrow Gauge).

Leaving the picturesque town of Los Gatos, the southbound train ascends the wild and beautiful cañon of Los Gatos Creek, crosses a double summit and by easy grades descends into the fertile Santa Cruz region. In the short time of two hours the traveler passes from the wheat-fields of Santa Clara Valley, through the orchards and vineyards of the foothills, into forests of gigantic redwoods and wild mountain scenery, thence to park-like glades and lawns stretching to the yellow sands and blue waters of Monterey Bay.

There are on this line two summit tunnels, the first or most northerly of which is just at Wright's Station, and is known as Wright's Tunnel. It is 1.16 miles long, and for some two hundred feet from the northern end is driven through a clay stratum resting upon an inclined

* Manuscript received September 2, 1895.—*Secretary, Ass'n of Eng. Socs.*

rock bed which pitches northward towards Los Gatos Creek. The maintenance of this tunnel has always given trouble during the heavy winter storms for which this immediate section of country is remarkable, but no serious impediment to traffic occurred until the winter of 1892–3.

At this place, a tributary to Los Gatos Creek, which flows nearly due east, is joined by a side creek flowing north. Both creeks are nearly dry in summer, but become torrents in stormy weather. The railroad track crossed the side creek just at the mouth of the tunnel and a few feet away from its junction with the north creek.

In the heavy storms of 1892–3, the two creeks cut through the clay bed to the rock below, and the whole hillside for some three hundred

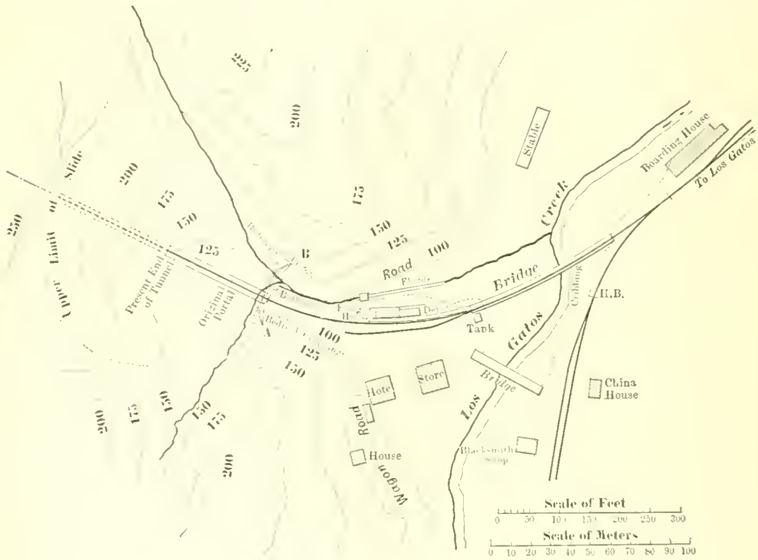


FIG. 1.

feet back slid forward towards Wright's Station, filling the narrow throat between the points of rock "A" and "B" on the accompanying map. The entire mass seemed to be afloat on a film of water between the clay and bedrock. The first two hundred feet of tunnel was crushed in and taken with the slide, and traffic on the road was stopped.

Attempts were made to reconstruct the end of the tunnel and portal with heavy timber and iron, but these proved failures. Not until the storms ceased, and a through cut was made, could traffic be resumed. As soon as dry weather set in, all was well; but it was evident that before the next winter one of the following courses of action must be taken:

(1) Do nothing, and abandon the road until spring.

(2) Hydraulic the slide out. As the condition of the bed beyond the slide was unknown, and as an inspection showed the ground to be seriously cracked for a considerable distance beyond the slide, it might prove to be a very serious undertaking, besides interfering greatly with the water supply of the town below, derived from the Los Gatos Creek.

(3) Re-establish and maintain the toe of the slide by raising the beds of the two creeks and by constructing a concrete masonry retaining-wall or dam from the rock points "A" and "B," pierced by a tunnel.

This last proposition, which originated in a discussion between Mr.

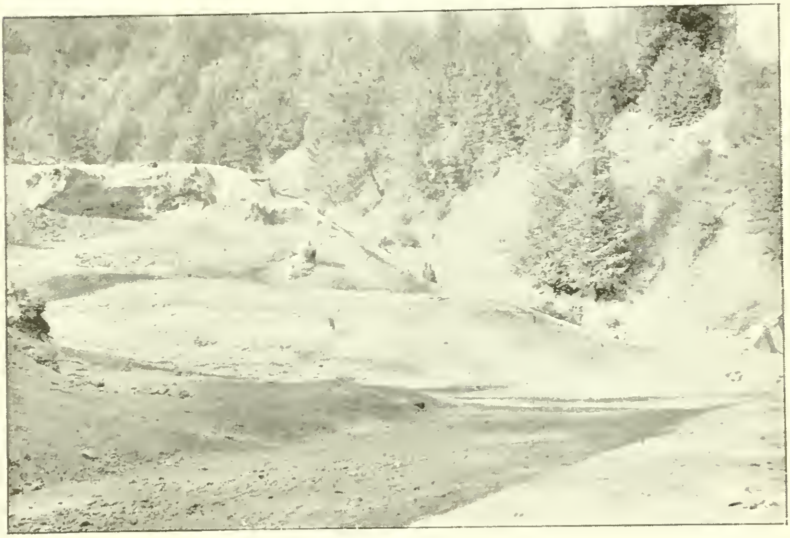


FIG. 2.

W. S. Palmer, Resident Engineer of the Santa Cruz Division, and our Vice-President, Mr. W. G. Curtis, was carried out, with highly gratifying results. A concrete retaining-wall was built, as shown on the accompanying drawings, pierced by a tunnel. The beds of the creeks were filled, re-establishing the toe of the slide, and the side creek from the south carried behind the wall over the top of the tunnel and made to join Los Gatos Creek just at a spillway in the westerly side of the retaining-wall, through which the combined streams now discharge.

The retaining-wall is about twenty-eight feet high from base of rail, fourteen feet thick at bottom and two feet thick at top. It is of the outline and form shown on plans herewith. The tunnel is oval in shape, and of varying thickness, as shown.

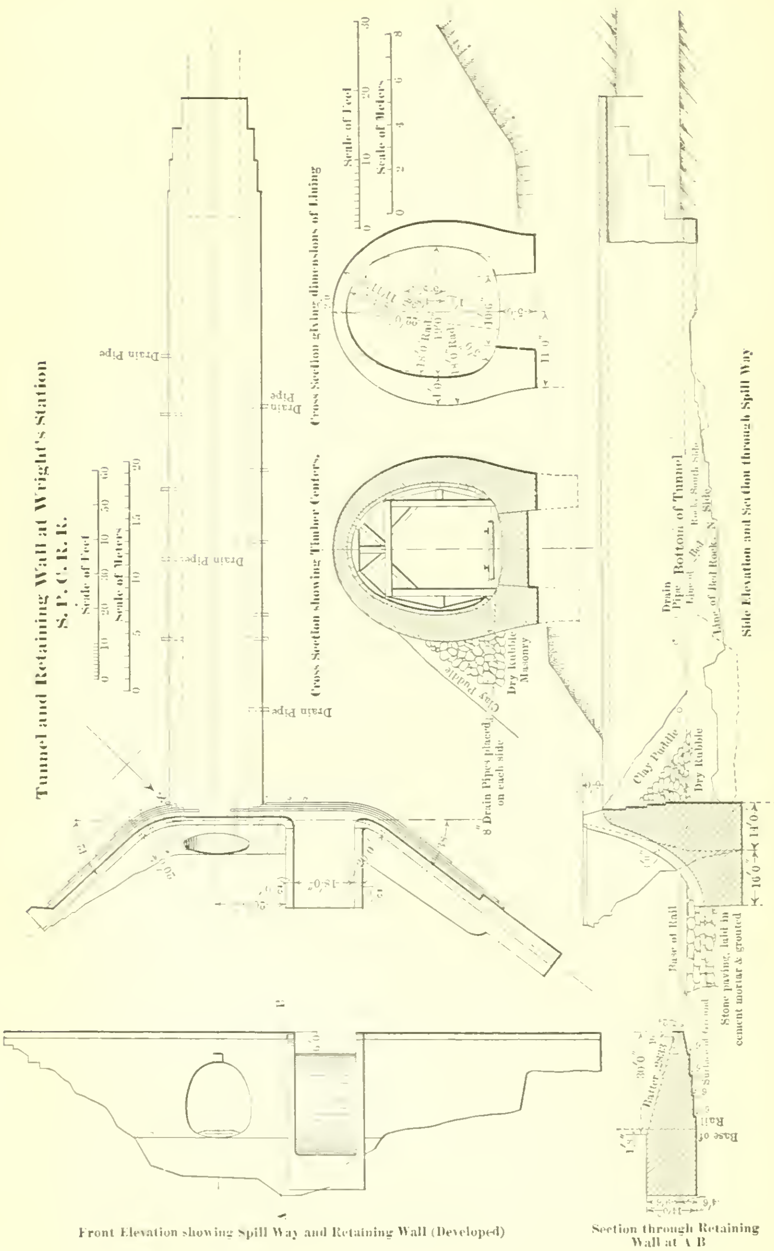

Tunnel and Retaining Wall at Wright's Station
S. P. C. R. R.
Scale of Feet
Scale of Meters
Drain Pipe
Cross Section showing Timber Centers.
Cross Section giving dimensions of Lining
Clay Puddle
Dry Rubble Masonry
8" Drain Pipes placed on each side
Bottom of Tunnel
Line of Bed Rock, N. Side
Side Elevation and Section through Spill Way
Dry Rubble
Base of Rail
Stone paving, laid in cement mortar & grouted
Front Elevation showing Spill Way and Retaining Wall (Developed)
Section through Retaining Wall at A B

FIG. 3.

As it was desirable to avoid hydrostatic pressure on the retaining-wall, it was backed by dry rubble masonry, which was covered with clay puddle, well rammed, and separate drains were run from the rubble and from the slide behind it through the retaining-wall. The same arrangement was followed with the masonry tunnel.

As the tunnel cut through the slide, it had to be arranged to transmit the thrust of the slide from south to north. The sides of the barrel were, therefore, carried down to bedrock, and a key-piece put in under the track, as shown. The earth was well tamped and rammed on both sides of the barrel, and the top of the tunnel was loaded with earth from

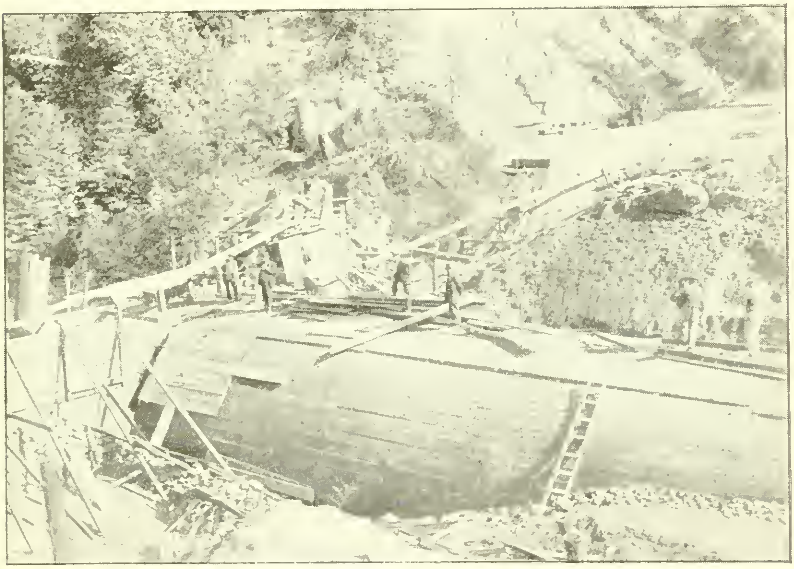


FIG. 4.

fifteen feet deep forty-two feet back from the retaining-wall, to twenty-five feet deep at its further end. In effect, the barrel was made part of the slide, and the slide provided with a toe.

MASONRY.—The entire work is a concrete monolith. All the concrete is mixed in the following proportion, by volume:

> One part Portland cement,
> Two parts sand,
> Three parts gravel,
> Four parts broken rock passing through a two-inch ring.

But all that portion below the base of rail, except the key-piece under the track, has placed in it large pieces of rock varying from one-quarter to one cubic yard, as follows: a layer of concrete six inches thick, hav-

ing been first laid, and while yet soft, large rocks were placed upon it, with their best bed down, the rocks usually standing on one of their ends, leaving a clear space of about eighteen inches between them, into which the concrete was afterwards rammed until the spaces were filled. Whenever there was room enough, smaller stones were thrown in and rammed with the filling, but care was always taken to surround all rock with concrete. It was thought by placing the large stones smaller side down they would bed themselves better in the soft concrete.

One tier or course having been thus built, the same method was pursued until the height of base of rail was obtained; above that, the same concrete mixture was used minus the large stones.

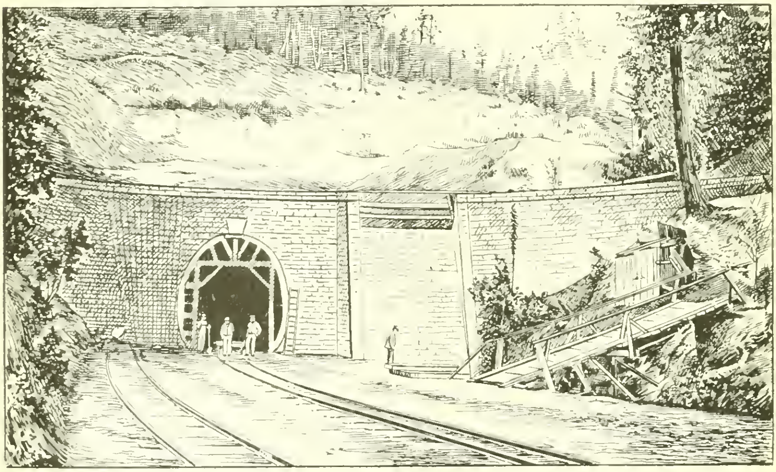


FIG. 5.*

The rock was a strong, heavy blue trap, obtained from the side of the road about three-quarters of a mile below the tunnel.

Sand and gravel were found mixed in nearly the proper proportion in a gravel bed just south of Campbell's, about ten miles north of the tunnel. Into this a series of spur-tracks were run, and the mixed sand and gravel loaded directly from the bank to the cars. A portion of this sand and gravel was screened and kept on hand separately, and additions of sand or gravel made as necessary.

MIXING.—Advantage was taken of an existing sidetrack put in when the cut was first opened, some thirty feet south of the main line and four feet above same, and the space between the two tracks

* The wall is of concrete, as stated in the text, not of masonry, as shown in the cut.—*Secretary, Ass'n of Eng. Socs.*

filled in with a mixing platform having its planking lengthwise. The top of this platform was level with the top of the cars on the siding and the planks over the proposed foundation left loose. Beyond the siding and further south the ground was benched at intervals level with the top of cars, and on these benches the cement was stored, making in effect, with the tops of the empty flats, a platform about forty feet wide. A train of cars loaded with rock was run on the siding, unloaded on the platform, distributed and wet down. This was pulled out and another followed with the proper amount of mixed sand and gravel. As soon as the last was unloaded, spread over the rocks and wetted, the barrels of cement were rolled across the flats, broken and distributed. Mixing with shovels then began, each turn bringing the mixture nearer the point of use, at which point the platform planks were removed so that the concrete dropped through to the rammers. For the north side, small removable troughs were used until such a height was attained that barrows were necessary. This arrangement enabled us to build the greater part of the mass with little use of barrows, but from a height of four feet from base of rail up, all the concrete was put in with wheelbarrows. The mixing board was near the track below the wall. The men made a circuit with the barrows. When each man returned to the mixing board with an empty barrow, another filled was ready for him, so that there was no waiting for loads. Tamping was done with point rammers weighing ten pounds each. Segments and lagging were made of two-inch plank, falsework of 12 x 12 inch timber. The tunnel is made sufficiently large to enable us to broad-gauge the road at any future time. The work occupied about six weeks, about one month being required for putting in concrete. The entire work contained about four thousand cubic yards of concrete. Exclusive of moulds, the concrete cost $6.00 per yard in place; to which the moulds would add 20 per cent. per yard. The falsework was allowed to remain during the winter of 1893–4, but was removed during last summer. Up to this date the structure shows no cracks or other sign of failure, and is apparently good for all time.

DISCUSSION.

The President.—This is a very interesting account of the troublesome work on the Santa Cruz Road. It ought to be interesting to the civil engineers present, and I hope the paper will be discussed.

Mr. Manson.—Mr. President, I heard Mr. Isaacs give a general description of this work when it was in progress. It was of great interest at that time, and now it is of more interest, the work having been successfully completed, and so well described.

I would ask Mr. Isaacs why he did not use the large rock above the level of the track in the wall? Was it because of the diminished thickness of the wall, or because it was more desirable to have the wall above the track constructed homogeneously?

Mr. Isaacs.—It was for both reasons.

Mr. Dickie.—What was the effect on the cost? I presume that was the main factor in using them?

Mr. Isaacs.—I put the rock in for about sixty cents a yard and the concrete would cost eight dollars a yard. I do not see the sense of breaking up rock and cementing it together again, where you can use large masses. I could not see any reason why below the line of thrust we could not use almost anything sufficient to sustain the weight.

Mr. Manson.—I asked the question because I have always been a strong advocate of using heavy masses of rock in heavy masonry, where the rock is sound. In some instances, where I could get large rock, I have used it freely. In certain cases its use materially reduces the cost, and with good results.

Mr. Randell Hunt.—Has there been any movement of the side-hill or the top?

Mr. Isaacs.—Not that I have observed. I have examined it several times. Some of the cracks above the actual slide seem to have settled together, but I think more from weathering than anything else.

Mr. Hunt.—About how far back did you notice the movement in the hill?

Mr. Isaacs.—The actual slide was, at the farthest point, about four hundred feet back. We could trace cracks for half a mile up the side of the mountain.

Mr. Hunt.—Was it a rocky side hill?

Mr. Isaacs.—It was of decomposed rock, mixed with clay: a bluish-black clay; and under that was a stratum of hard country rock, pitching nearly in the direction that the slide took.

Mr. Hunt.—Did you take any means to drain the side hill afterwards—up on the hill?

Mr. Isaacs.—No, except through the dam.

Mr. Grunsky.—I would like to know what water was developed or what water was moving between the clay and the rock. We have recently had occasion to consider that question in the building of an earth dam with a rock foundation. We put in what might be called a core wall as a support for the earth dam. Just above the wall we put in some dry rock filling to create a sort of sump, and above that some

finer material. Then we put in a lead pipe from that sump to the toe of the dam, to show what was going on underneath the structure. The work seemed to have been satisfactorily done. There was really no leakage, and no water reached our broken rock at all. This may be an instance where it is possible to determine what the flow was between the clay and hard rock underneath it.

Mr. Isaacs.—I was at Wright's last winter, and I noticed there was some little dripping from the pipes that had been put into the rubble backing. Whether it got through the clay, or whether it followed down the concrete, I do not know. There was quite a little stream running from each of the pipes that were put through the puddle.

Mr. Hunt.—Mr. Chairman, this paper of Mr. Isaacs, which he has presented so clearly, brings to my mind some experiences I have had at various times with regard to very large clay slips, and particularly in railroad practice. I know of instances of alluvial deposits in rivers, where a clay bank on the concave shore is continually slipping forward, and railroads constructed along such a river bank have frequently met with mishap, due to the sliding forward of these large clay banks.

The usual remedy is in the nature of preventing such slips by drainage of the sidehill quite a distance back from the works. That is the reason I asked Mr. Isaacs whether he attempted anything of that kind to prevent future action. The cause of these great movements of sidehills and clay slips I have found to be water, which gets into the soil and seeks an outlet, generally through some permeable stratum. In the Red River Valley in North Dakota, a large area of land, embracing probably fifteen or twenty acres, slid forward, not quickly, but during a number of years, until it got down to an exceedingly flat slope. Nevertheless, it continued to move forward and carried with it a large bridge pier that was founded on piles forty feet in the ground. In seven years it moved about ten feet, so that the pier, which was under the end of a Howe truss bridge, was pushed under the second panel point. The movement was perfectly irresistible. No method, as far as could be seen, could be used to hold it back.

I know of a case also in California, in the mountains of Mendocino County, on Eel River. The side of the mountain started to move. It was due to water getting into the sidehill quite a distance back from the river, and it was pushing the whole side of the mountain down into the river. In this case any further progress was prevented by a very simple method of draining the sidehill about a thousand yards back. A few cross ditches carried the water away, and since then no further movement has been discovered.

Mr. Isaacs.—Before this work at Wright's Station was undertaken we discussed the matter of drainage pretty thoroughly. This tunnel had always given trouble in the heaviest winters. This section of country (I think Mr. Manson and Mr. Grunsky will bear me out) has about the heaviest rainfall of any section in California on the line of the Southern Pacific Railroad except Mount Shasta. We had already attempted to prevent the sliding by ditches, just beyond the gap, leading off both ways according to the slopes of the ground to the side creeks. But that did not stop it. The difficulty here seemed to be that the mountain side was composed of a broken-up soil, consisting of fine, decomposed rock and clay and various other materials, all mixed up together, and it lay on a pitching bed of rock. This mass was left with perpendicular sides and no toe, and it simply slid along. In the time at our disposal, with ground of such character, and with a large rainfall, we could not put in enough ditches to intercept the rain and prevent it getting down into the crevices. All sorts of suggestions were made about this work. One suggestion was to build a shed over the whole mountain side and keep the rain off.

Mr. Hunt.—Such slides occur where the water gets in behind and then sweeps down underneath the surface strata. I have usually found these slides in a clay bank, and where there are permeable strata. In one particular instance I argued that a stratum of sand was causing the trouble. We were sinking a large circular pier, thirty-two feet in diameter, and this clay bank was coming in on us. After we got down quite a distance, we came into a stratum of river quicksand a few inches in thickness, and this, no doubt, was the cause of the slip. The water got behind and into the clay, and the whole bank moved forward on the slide thus formed.

It has been my experience that blue clay seems to be the most slippery, and that the most irresistible slides are those caused by it.

In one case, when we had a very bad drought, the next season the bank moved more than usual. That was probably due to the fact that during the drought the heat cracked the clay bank, so that they were more apt to break open and leave fissures in the ground; then the rain would come on afterwards, the fissures would fill up with water, and the hydrostatic pressure would become enormous. I suppose this is the cause of nearly all these slips.

Mr. Manson.—The matter of sliding hillsides is exceedingly interesting here in California. You find it not only along the line of newly constructed works, but along creeks. On hillsides and on mountain sides the evidence of it is very distinct, and very interesting to study.

The California clays, and particularly those that are the result of

the decomposition of an impure soapstone we have here, are very apt to slide. Mr. Schussler says, he believes they would slide up hill. He has had very disastrous experiences with them in connection with his pipes.

Mr. Hunt.—A very large slide took place in Germany some years ago, and it was very successfully treated by means of a deep ditch on the upper side. It was carried underneath the railroad embankments, and side lateral ditches were run in both ways parallel to the railroad.

DEFLECTIONS AND STRAINS IN A FLEXIBLE RING UNDER LOAD.

By William H. Searles, C.E., Member of the Civil Engineers' Club of Cleveland.

[Read before the Club, July 9, 1895 *.]

If we suppose a flexible ring of uniform section to stand vertically, resting on a single point, and to be loaded at the top, a number of interesting problems at once present themselves for solution, such as:

What load will be required to produce a given depression?

What will be the horizontal extension of the ring under the same load?

What is the relation between the vertical and horizontal displacements?

What is the general relation between loads and vertical depressions?

What are the principal moments of resistance, at the side and top?

What is the position of the section of no moment at any period of deflection?

What is the radius of curvature at the side or at the top under any condition of load or depression, and at what point of depression does the radius of curvature become infinite?

Again, the same questions arise if we suppose the load to be replaced by a vertical pull, changing the ring from a roller into a link.

The Club has already listened to a paper on the compressive strength of steel hoops by Prof. C. H. Benjamin,† the publication of which led Messrs. C. W. L. Filkins and Edwin J. Foot, Civil Engineers of Cornell University, to offer an elaborate mathematical analysis of the conditions of a rigid ring under external load. Their conclusions and formulas, though applicable only to a ring which remains sensibly circular under load, are adopted here and form the basis or starting point of the present investigation.

The experimental data were derived from a ring of No. 9 steel wire electrically welded, having a mean diameter of 20 inches. The ring was compressed one quarter inch at a time, the load read on a spring balance, and the shape of the hoop traced at each inch of compression, the geometric center of figure being kept identical in all cases.

* Manuscript received September 25, 1895.—*Secretary, Ass'n of Eng. Socs.*

† Journal for December, 1893.

The ring was also subjected to tension, and a record of forces and shapes made in a similar manner. These experiments, though crude enough, were satisfactory up to the limit of elasticity. Beyond that point they were supplemented by experiments upon hoops of band-steel which would bear entire collapse under pressure, reducing one diameter to zero, and yet would recover their original shape fairly well.

As the figure of the hoop is always symmetrical about its two principal axes we may confine our attention to a single quadrant, taking the origin of co-ordinates at the center of the entire figure, and calling the vertical semi-diameter, Y, and the horizontal semi-diameter, X. For the circle, $Y = X = R$. Let $\triangle Y$ denote the compression due to a

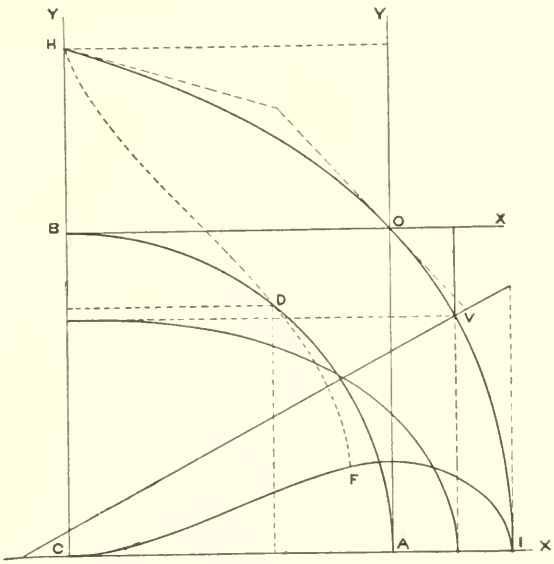


Fig. 1.

load and $\triangle X$ the horizontal extension, while the center C remains stationary. Suppose the vertical radius to be divided into ten equal parts and the hoop compressed successively to each point of division. We shall then find that X has been extended by ten unequal increments which gradually decrease toward the end of the experiment. If we extend Y by equal increments, X will be reduced by rapidly increasing increments. If we draw perpendiculars through the corresponding points of division, their intersections will lie in a curve. (Fig. 1.) This curve, of course, passes through the point O where the tangents to the circle meet, it crosses the axis of Y at H, CH being equal to the length of the quadrant and is the value of Y when $X = O$. The curve also cuts the

axis of X at I, when $Y=O$. The tangent at I is assumed to be at right angles to CI.

To find the tangent at O we refer to the paper above mentioned which demonstrates that if $\triangle X$, $\triangle Y$, represent the first minute changes in the value of the radius R of a circular ring under a load P, then

$$\triangle X = \frac{4-\pi}{4\pi} \cdot \frac{P R^3}{E I} \text{ and } \triangle Y = \frac{\pi^2-8}{8\pi} \cdot \frac{P R^3}{E I}. \qquad (1)$$

Consequently, if i is the inclination of the required tangent at O to the axis of Y, we have by division,

$$\tan i = \frac{\triangle X}{\triangle Y} = \frac{8-2\pi}{\pi^2-8} = .91828 \qquad (2)$$

or $i = 42°33'38,''$ a constant, and therefore true, for all hoops. Having now three points through which the curve of XY passes and the direction of the tangents at two of them we determine by graphical tests that this curve can only be a common parabola, but its axis does not pass through our origin C, nor is it parallel to either axis of co-ordinates.

The finding of the axis of the parabola, its focus, etc., by analysis is a neat little problem, which, however, need not be gone into here. Suffice it to say that, $C\,H$ being equal to $R\ \frac{\pi}{2} = R\ 1.5708$, and $C\ I$ equal to R 1.3673 and the tangents to the curve at O and I being as stated, the axis of the parabola is inclined to the axis of X by an angle of $28°\ 33'\ 49''$ and cuts the axis of X at a point .14461 R beyond or to the left of the origin C. The co-ordinates of the vertex V are $X = 1.19450\ R$, and $Y = .72900\ R$. The parameter is $2p = 2.6558\ R.$, in which R is the mean radius of the original hoop.

This parabola solves the third question of the series, giving by its co-ordinates the relation between the vertical and horizontal displacements. The calculation of value of $\triangle X$ in terms of $\triangle Y$ is rather tedious. The equation of the curve, referred to the axes $X\ Y$, is too complex for convenient use, but a double transformation of co-ordinates is practicable. Taking the origin for $\triangle X$, $\triangle Y$ at O, and taking the origin for the co-ordinates $\triangle Y$ of the parabola at its vertex V, and letting a, b represent the distance between origins measured on $\triangle Y$, and $\propto$ the inclination of the axis to X as given above, then for any value $\triangle Y$ corresponding to the point M on the curve between O and V we have

$$(b - \triangle Y) = y \cos. \propto - x \sin. \propto$$

But for the parabola $x = \frac{y^2}{2\,p}$

$$\therefore \quad y = p \text{ cot. } \alpha - \sqrt{p^2 \text{ cot.}^2 \alpha - \frac{2\,p\,(b - \triangle\,Y)}{\text{sin. } \alpha}} \tag{3}$$

from which value we find that of $x = \frac{y^2}{2\,p}$ and finally

$$\triangle\,X = a - (x \text{ cos. } \alpha + y \text{ sin. } \alpha) \tag{4}$$

The same formulas apply to any point M on the curve above O or below V, with suitable change of signs. Having calculated a series of values of $\triangle\,X$ we have only to add them to R, (or subtract for points above O) to obtain the values of X referred to the origin C, since the ordinate $\triangle\,X = X - R$. By this method all tabulated values of X given below have been calculated. The parabola below O represents compression (Y less than R) and above O extension (Y greater than R). It applies to all circular rings of whatever section or diameter. Its determination, as we have seen, is a purely geometrical problem, being independent of the amount of force or load required to produce distortion in the ring. Its form is always the same. If drawn to scale for a ring of unity, its ordinates $\triangle\,X\ \triangle\,Y$ multiplied by the radius of another ring will give the amount of distortion for the latter.

To investigate the law governing the loads required to produce a given series of depressions, reference was had to the experiments made upon the 20-inch ring. Drawing a vertical line OA, 10 inches long to represent the radius, and dividing each inch into eighths, horizontal lines were drawn through the points of division, on which were laid off, to a scale of ten pounds to an inch, the actual loads deduced by experiment. A line drawn through the extremities of these ordinates approximated a curve, the character of which was not obvious at first, owing to the permanent set that occurred in the ring as the load increased.

To find the tangent to the force-curve at O, where the load P equals zero, we quote again from the Cornell paper the equation giving the relation between the load and depression while the ring remains circular, viz:

$$\triangle\,Y = \frac{\pi^2 - 8}{8\pi} \cdot \frac{PR^3}{EI}.$$

If in this, we replace P by $\triangle\,P$ to represent the load producing the first indefinitely small depression $\triangle\,Y$, and then multiply $\triangle\,P$ by S. $(=10)$ to reduce inches to pounds, we have:

$$\triangle\,Y = \frac{\triangle\,P.S.R^3}{EI} \cdot \frac{\pi^2 - 8}{8\pi}$$

Now dividing by $\triangle\,Y$, and letting $u =$ the inclination of the tangent line to the vertical:

$$\tan. u = \frac{\triangle P}{\triangle Y} = \frac{8\pi}{\pi^2 - 8} \cdot \frac{EI}{SR^3} \tag{5}$$

An examination of the form of the hoop as traced at certain stages of the experiment showed that at one stage of depression the top of the hoop becomes perfectly flat, although loaded at a single point, and this was found to occur exactly at the level of V, the vertex of the parabola. With any increase of load after this, the curvature is reversed in the top of the hoop, and when the hoop is entirely collapsed, or $Y = o$, the radius of curvature appears to be just one-half of the original radius R.

Now it is a well-known principle of mechanics, that if an elastic straight bar be bent into a circular form and the ends united, the ring will be, theoretically, a perfect circle, and a moment of resistance will be developed in every section of the material tending to restore the ring to a straight line the instant that the ends are released. This uniform moment is expressed by $\frac{EI}{R}$, or the product of the modulus of elasticity into moment of inertia of the cross-section divided by the mean radius of the ring.

Conversely; if an elastic ring, normally circular, be so compressed as to reduce a portion of it to a straight line, the moment of resistance developed in that portion will be $\frac{EI}{R}$ as before. And if the pressure be increased until the radius of reversed curvature becomes equal to the original radius the moment of resistance of the section will then be $2\frac{EI}{R}$. If by further pressure the reversed radius be reduced to one-half the original radius the resulting moment will be increased to $3\frac{EI}{R}$; and so on.

If then M_B represents the variable moment at the section B,

For level of	B	$\triangle Y = O$	$M_B = O$	$R_B = R$
"	V	$\triangle Y = .2709974R$,	$M_B = \frac{EI}{R}$	$R_B = \infty$
"	$?$	$\triangle Y = ?$	$M_B = 2\frac{EI}{R}$	$R_B = -R$
"	C	$\triangle Y = R$	$M_B = 3\frac{EI}{R}$	$R = -2R$

and in general

$$M_B = \left(1 - \frac{R}{R_B}\right)\frac{EI}{R} \tag{6}$$

in which $R_B =$ the variable radius of the hoop at the point of application of load.

We thus know the value of the moment M_B for three positions of the point of application of force, and if we knew the lever arm in each case we could calculate the force exerted.

Now the Cornell paper demonstrates that for a rigid circle the sum of the two principal moments (at A and B) is

$$M_A + M_B = \frac{PR}{2}$$

As the flexures at A and B are contrary, there must be, on the quadrant between them, a point of no flexure, and consequently of no moment. This point is proved to be at D, the horizontal ordinate of which is $\frac{2}{\pi}R$. The point D is the center of moments for the circular ring, and $\frac{2}{\pi}R$ is the lever arm for the moment at B. Therefore, for the circle,

$$\left.\begin{aligned} M_B &= \frac{PR}{2} \cdot \frac{2}{\pi} = \frac{PR}{\pi} \\ M_A &= \frac{PR}{2}\left(1 - \frac{2}{\pi}\right) \end{aligned}\right\} \tag{7}$$

A careful study of the several shapes of the ring, traced at successive stages of compression, served to locate with considerable accuracy the point in each case where the radius of curvature was equal to the original radius R. These points taken together gave a fairly regular curve, and an average curve drawn among them was taken to be the curve of no moment, or the *locus* of the center of moments for all stages of compression. See $H\ D\ F$, Fig. 1.

It was then discovered that the horizontal ordinate to the intersection of the *locus* with the compressed ring bore a constant ratio to the value of X for the same stage of compression (X being the horizontal semi-diameter); and that this ratio is identical with the ratio established by theory for the lever arm in the circle. Calling the two lever arms at any stage X_A and X_B, respectively,

$$X_A + X_B = X$$

$$X_B = 2\frac{X}{\pi} \text{ and } X_A = X\left(1 - \frac{2}{\pi}\right) \tag{8}$$

Consequently

$$M_B = \frac{P}{2} \cdot \frac{2X}{\pi} = \frac{PX}{\pi} \qquad M_A = \frac{PX_A}{2} = \frac{PX}{2}\left(1 - \frac{2}{\pi}\right) \tag{9}$$

The discovery of the permanence of this ratio is probably the most important one in the whole investigation. We have now only to resolve the last formula to obtain

$$P = M_B \frac{\pi}{X} \tag{10}$$

Giving to M_B and X the particular values found for them for the level of the vertex V, we obtain the corresponding value of P; similarly we find the value of P for the state of collapse, and plotting these two values to scale we have two definite points, W and J, on the force-curve (Fig. 2), besides the point O, and the direction of the tangent at O. Drawing a curve through these points and through other points near O obtained by direct experiment, it became evident that the force-curve is an hyperbola. It was also evident that the vertex lay a short distance above the level of B, and that the axis through the vertex passes not far from the center C of the circle. The three known points of the

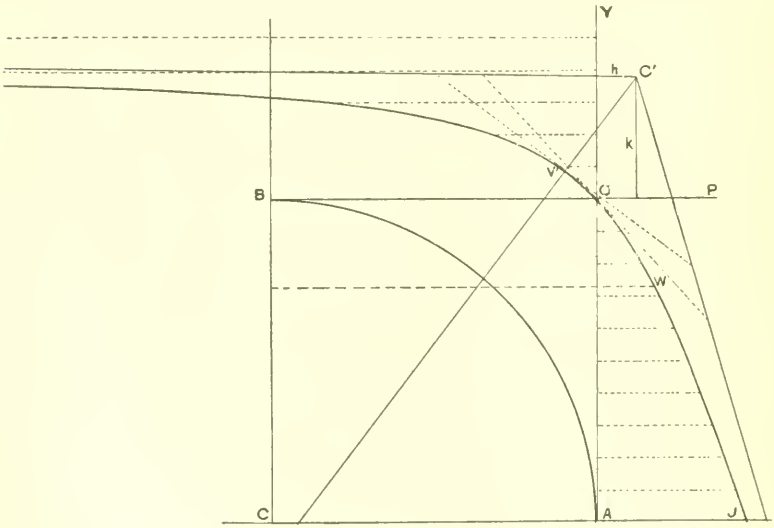


FIG. 2.

hyperbola are therefore all on one side of the axis, and the hyperbola beyond the vertex is given only approximately by experiment.

But if we consider the moments induced in the section A, we see that no amount of vertical tension applied at B can do more than straighten the ring at A; consequently the moment M_A can never exceed the limit $\frac{EI}{R}$; and this limit is only reached when the ring is drawn out to a straight line, and X is reduced to zero. At the same time the moment M_B under tension increased indefinitely by the action of the same force that produces M_A. It is obvious that the lever arms X_A X_B cannot maintain an invariable ratio on the tension side as they do on the compression side, but X_B must increase at the expense of X_A while their sum is always equal to the variable quantity X, the mean semi-diameter of the link. The change of ratio does not begin, however,

until the level of the vertex V' of the hyperbola is reached and is not perceptible until $Y = 1.10\ R$. At or near this point the curve of moments M_A undergoes reversion, and it finally becomes tangent to a line parallel to the axis of Y at a distance from it equal to $\frac{EI}{R}$ when Y reaches its maximum of $\frac{\pi}{2}R$.

This curve of M_A was drawn tentatively at first on the tension side, as also the curve of P; and $X_A = \frac{M_A}{\frac{1}{2}P}$ determined for a number of points. Then $X_B = (X - X_A)$ was found, and finally $M_B = \frac{P}{2}X_B$. The half load only is employed, because by supposition the load P is equally divided between the two sides of the ring, and we are considering only one side. After a number of trials, a set of curves for loads and moments in tension was arrived at that seemed to satisfy all conditions reasonably well.

The force-curve is required in any case to pass through the given points O, W, J, and to have a tangent at O, making the given angle u with the axis of Y. Any change in the assumed position of the vertex V' or direction of axis $V'\ C'$ would make very slight impression on the compression side of the curve while making a wide divergence on the tension side. Experiments are needed in the high tensions upon a ring of great elasticity, to fix definitely a few points well out on the tension end of the force-curve, but in their absence the present results are offered as fair approximations through the whole range, and very close to the truth on the compression side, and as far as 1.10 R in tension.

The axis of the hyperbola can have but one direction for a given position of the vertex, otherwise the angle u would be altered, yet the relation between them is not easily expressed. Having decided upon the direction of the axis, or the angle β that it makes with OY, the position of the vertex was found, after a few trials, such as to give u the required value.

The value of the modulus of elasticity of the steel wire in the experimental ring was taken at,

	$E = 28{,}666{,}890$	[7.4573805]
and the moment of inertia		[5.3720167]
Hence $EI =$	675.1452	[2.8293972]
$\frac{EI}{10R^3}$	.06751452	[8.8293972]
The constant $\frac{8\pi}{\pi^2 - 8}$ is		[1.1284902]
$\therefore$ tan. u = tan. 42° 13′ 35″.11		[9.9578874]

Calling the force required to compress the hoop to the level of V, P_1 :—

$$P_1 = M_B \frac{\pi}{X_1} = \frac{EI}{R} \cdot \frac{\pi}{X_1} = \qquad 17.75658 \qquad [1.2493594]$$

If P_2 is the force required to collapse the hoop to the level of the center :—

$$P_2 = M_B \frac{\pi}{X_2} = \frac{3EI}{R} \cdot \frac{\pi}{X_2} = \qquad 46.53673 \qquad [1.6677959]$$

since $X_1 = 11.945042$ and $X_2 = 13.67325$ for the parabola, as we have already seen. The values of P_1 and P_2 are thus calculated independent of experiment as soon as E is determined, and since the ordinates representing them are plotted to the scale of $\frac{1}{10}$, we must take one-tenth their value as the ordinates to the hyperbola.

The direction finally fixed upon for the axis of the curve makes an angle with the axis of Y of $\beta = 37° 15'$ on the opposite side from the angle u. The next step is to calculate the semi-axes, a and b, of the hyperbola passing through the three given points, with the given tangent at O, to locate the center and vertex, and to find the co-ordinates $x_0\ y_0$, $x_1\ y_1$ and $x_2\ y_2$ of the three given points, referred to the axis and center of the hyperbola. Not to burden this paper with these mathematical pyrotechnics, let us assume this work accomplished, and we find as results :

y_0	1.291056	[0.1109451]	x_0	3.758851	[0.5750551]
y_1	4.344814		x_1	4.841201	
y_2	11.048329		x_2	8.902030	

For the semi-axes:

$a = 3.636958$ [0.5607383] $b = 4.945402$ [0.6942016]

Note that a is less than b, showing that this is what is usually called a conjugate hyperbola.

If we let h and k stand for the co-ordinates of the center referred to the origin at O and axes XY, then :

$h = 1.247527$ $k = 3.773522$ [0.5767469]

With these quantities we may construct the hyperbola and scale off the horizontal ordinates at any point above or below O corresponding to $\pm \triangle Y$, the ordinate giving one-tenth $(\pm P)$ in each case.

To calculate P for any exact value of $\triangle Y$ we resort, as in the case of the parobola, to a double transformation of co-ordinates. Assuming $\triangle Y$ giving a point M, on the hyperbola, find x, then y, and from these find $\frac{P}{10}$ for the same point M.

The formulas for this calculation for points below O, or when P is positive, are:

$$x = -(k + \triangle Y)\,A \cos.\beta + \sqrt{(k + \triangle Y)^2\,[A^2 \cos.^2\beta + A] + Ab^2 \sin.^2\beta} \qquad (11)$$

in which $A = \dfrac{a^2}{b^2 \sin.^2\beta - a^2 \cos.^2\beta}$, a constant ratio,

$$y = \frac{(k + \triangle Y) - x \cos.\beta}{\sin.\beta} \quad \text{or} \quad y = \sqrt{\frac{b^2}{a^2}(x^2 - a^2)}, \qquad (12)$$

and

$$\left(\frac{P}{10} - h\right) = y \cos.\beta - x \sin.\beta. \qquad (13)$$

The same formulas, with suitable change of signs, apply to finding P in tension, or $-P$. By this method all the values of P were obtained, as given in the following table:

TABLE I.—VALUES DERIVED FROM EXPERIMENTAL RING.

$R = 10. \qquad EI = 675.1452.$

Y	P lbs.	X ins.	M_A	M_B	R_A ins.	R_B ins.
	−	+	−	−	+	+
15	819.9721	2.0980	67.301	792.85	3154.6	.7847
14	305.0290	4.4367	65.613	611.04	354.99	.9950
13	82.0106	6.2787	58.667	198.80	76.278	2.5322
12	30.8645	7.7679	41.188	78.688	25.645	4.6178
11	11.1886	8.9898	18.275	32.018	13.711	6.7833
10	0.	10.	0.	0.	10.	10.
	+		+	+		
9	7.8199	10.8372	15.3975	26.975	8.1429	16.6544
8	13.9771	11.5295	29.279	51.296	6.9721	41.611
						± ∞
7	19.1993	12.0883	42.203	73.935	6.1535	105.152
6	23.8400	12.5600	54.404	95.313	5.5377	24.283
5	28.0967	12.9278	65.995	115.622	5.0647	14.035
4	32.0867	13.2123	77.027	134.947	4.6710	10.0125
3	35.8845	13.4223	87.512	153.316	4.3550	7.8686
2	39.5380	13.5651	97.447	170.722	4.0927	6.5415
1	43.0805	13.6470	106.820	187.141	3.8728	5.6435
0	46.5367	13.6733	115.614	202.545	3.6867	.5

The values of the moments M_A, M_B are the products of $\frac{1}{2}PR$ by the respective lever-arms X_A, X_B which are given in Table II. Although the bending at A and B is contrary, one being outward when the other is inward, the moments at A and B take the same sign; *viz.* the sign of of P whether $+$ or $-$, since the lever-arms are considered positive throughout, and the two moments conspire to resist or balance the load at any instant.

The last two volumes give respectively the radius of curvature of the bent hoop at the points A and B. Under tension the radius R_A increases from 10 to infinity, while under compression it is diminished to 3.6867 for $Y = 0$, or $\triangle Y = 10$. The radius of curvature R_B, on the contrary, is decreased theoretically to zero under tension when $Y = 15.708$, but under compression increases rapidly to infinity when $Y = 7.290026$, and then, changing sign it is reduced from $-$ infinity to -5, or $-\frac{1}{2}R$, when $Y = 0$. When $Y = 4$ the value of R_B is -10.0125, or $-R$ very nearly. The formulas for obtaining R_A and R_B will be given later.

Since Table I only contains values applicable to the experimental ring it would seem at first to serve no purpose other than to illustrate the subject, but as we shall now see, we may from this construct a table applicable to all cases.

Taking any one line of the table and regarding the quantity in the first column merely as a proportional part of radius R, we observe from the preceding formulas that, when R is constant:

P varies as EI, X is constant, and M_A, M_B vary as EI.

But if EI is constant and R variable:

P varies as $\frac{I}{R^2}$, X varies as R, and M_A, M_B vary as $\frac{1}{R}$.

Therefore by combination; in general,

P varies as $\frac{EI}{R^2}$, X varies as R, and M_A, M_B vary as $\frac{EI}{R}$.

Now let Y be divided by R, to get Y of Table II. Let $K = \frac{PR^2}{2EI}$, taking R and EI from the head of Table I. Find X_A, X_B from X by equation (8), first dividing X by R, Table I, and place all the results in Table II. These are values corresponding to $R = 1$ and $EI = 1$; but $K =$ the *half* load.

If then we let A, B, be the principal moments for $R = 1$ and $EI = 1$ we have at once $A = KX_A$, and $B = KX_B$. Or we may obtain A, B, by multiplying M_A, M_B, each by $\frac{R}{EI}$. Table I.

To find the radius of curvature at B, we have from equation (6)

$$M_B = \left(1 - \frac{R}{R_B}\right)\frac{EI}{R}$$

whence

$$R_B = \frac{R}{1 - M_B\dfrac{R}{EI}}$$

and when

$$R = 1 \text{ and } EI = 1 \qquad R_B = \frac{1}{1 - B}$$

Similarly we may derive

$$M_A = \left(\frac{R}{R_A} - 1\right)\frac{EI}{R}$$

whence

$$R_A = \frac{R}{1 + \dfrac{RM_A}{EI}}$$

$$\text{and when } R = 1 \text{ and } EI = 1,\ R_A = \frac{1}{1 + A}.$$

In using A and B in these formulas, their algebraic signs must be regarded.

We may now prepare the following table, for general use:

TABLE II.—VALUES PERTAINING TO AN ELASTIC RING.

In which $R = 1$ and $EI = 1$.

Y	K	X_A	X_B	A	B	R_A	R_B
	−			−	−	+	+
1.5	60.726	.016416	.19339	.99683	11.7435	315.46	.078741
1.4	22.590	.043021	.40065	.97183	9.0504	35.499	.099498
1.3	6.0735	.143064	.48481	.86890	2.9445	77.6278	.25352
1.2	2.2857	.266895	.50990	.61006	1.1655	2.5645	.46178
1.1	0.82860	.326672	.57232	.27068	.47423	1.3711	.67833
1.	0.	.363380	.636620	.0	.0	1.	1.
	+			+	+	+	+
.9	0.57913	.393802	.689917	.22806	.39955	.81429	1.66541
.8	1.01312	.41896	.73399	.43367	.75977	.69751	4.1611
							$\pm\infty$
.7	1.42185	.43963	.77020	.62509	1.0951	.61535	10.5152
.6	1.76554	.45641	.79959	.80580	1.4118	.55377	2.4283
.5	2.08079	.46977	.82301	.97748	1.7125	.50647	1.4035
.4	2.37628	.48011	.84112	1.14088	1 9987	.46710	1.00125
.3	2.65755	.48774	.85449	1.29620	2.2709	.43550	.78686
.2	2.92817	.49293	.86358	1.44334	2.5287	.40927	.65415
.1	3.19046	.49590	.86880	1.58216	2.7718	.38728	.56438
0.0	3.44642	.49687	.87045	1.71242	3.	.36867	.5

K in lbs. A and B in lbs.-inches. The others in inches.

In order to apply Table II to any elastic ring of radius R, and elastic reaction EI, we have only to observe the following rules:—

To find the total load, $P = K \frac{2EI}{R^2}$.

To find the lower arms X_A X_B, multiply the tabular numbers by R.

To find the semi-diameter X, add together the lower arms just found.

To find the principal moments M_A M_B, multiply A and B of the table by $\frac{EI}{R}$.

To find the radius of curvature at A or B, multiply R_A or R_B (Table II) by R.

We are thus able to solve the problem of the elastic ring through the whole range of distortion, or as far as the elastic limit of the material will permit. Interpolated values may be used if necessary, in which case the second order of differences should be employed to secure accurate results.

TABLE III.—VALUES PERTAINING TO AN ELASTIC RING.

In which $R = 1$, and $EI = 1$.

$\triangle Y$	K	$\triangle X$	A	B	R_A	R_B
+	—	—	—	—	+	+
.10	.82860	.10102	.27068	.47422	1.37114	.67833
.09	.72752	.09004	.24056	.42145	1.31677	.70351
.08	.63150	.07927	.21129	.37016	1.26789	.72984
.07	.54009	.06869	.18278	.32021	1.22365	.75745
.06	.45288	.05832	.15497	.27150	1.18339	.78647
.05	.36950	.04814	.12781	.22391	1.14654	.81705
.04	.28964	.03814	.10124	.17736	1.11264	.84936
.03	.21301	.02834	.07521	.13176	1.08133	.88358
.02	.13934	.01871	.04969	.08705	1.05228	.91992
.01	.06841	.00927	.02463	.04315	1.02525	.95864
.00	.0	.0	.0	.0	1.	1.
—	+	+	+	+	+	+
.01	.06607	.00910	.02423	.04244	.97635	1.04433
.02	.12998	.01803	.04808	.08424	.95412	1.09199
.03	.19187	.02679	.07159	.12542	.93319	1.14341
.04	.25190	.03539	.09477	.16604	.91343	1.19909
.05	.31017	.04383	.11765	.20612	.89473	1.25963
.06	.36682	.05211	.14024	.24569	.87701	1.32572
.07	.42195	.06024	.16256	.28480	.86017	1.39821
.08	.47564	.06821	.18463	.32346	.84415	1.47811
.09	.52801	.07604	.20646	.36170	.82887	1.56667
.10	.57913	.08372	.22806	.39955	.81429	1.66541

K in lbs. A and B in lbs.-inches. The others in inches.

As most cases requiring solution will be concerned with a distortion $\triangle Y$ not exceeding $\pm \frac{R}{10}$, Table III has been prepared within these limits.

To find the limiting load, the maximum fibre-stress must be considered. If this be represented by p and the half thickness of the ring or pipe by e, since

$$M_B = \frac{pI}{e} = B\frac{EI}{R}$$

$$p_B = B\frac{Ee}{R} \text{ and } p_A = A\frac{EI}{R}$$

At A we have also the unit-stress of the half-load $\frac{P}{2}$ divided by the area, but this is relatively quite small. Since the ratio of B to A or p_B to p_A is never less than 7 : 4, and in high tension, much greater, p_B is greater than the sum of the unit stresses at A. There is neither thrust nor tension at B, but there is a shear, equal to half the load, near the point of application.

If we assume a limit for p we first find B by

$$B = p\frac{R}{Ee}$$

and opposite value of B in the table we find the other values required Thus taking the limiting value of the half load K for unity, we multiply it by $\frac{2EI}{R_2}$ to obtain the limiting value of P.

The hoop is assumed to preserve an invariable length under stress. It does so, sensibly in compression, and in moderate tension; but when pulled out into a flat link it will generally stretch so as to give results somewhat at variance with the theory of the elastic ring.

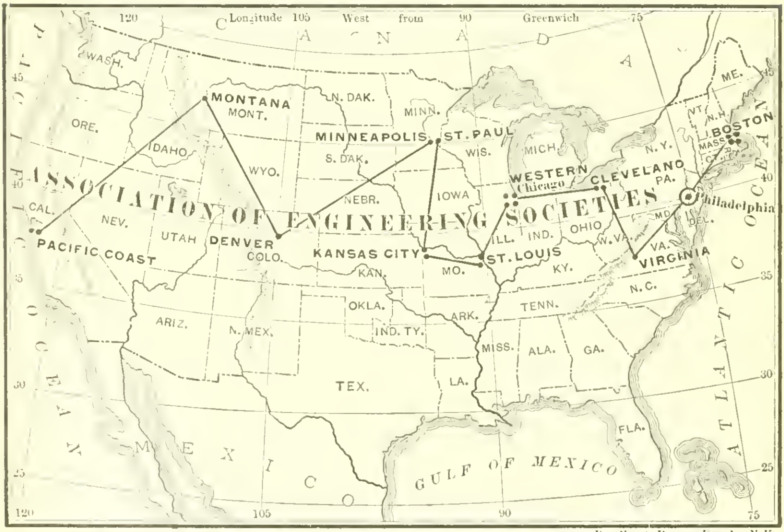
Unless the material is of uniform section and elasticity throughout it will yield most at the weakest point, thus disturbing the ratios of distortion, $\triangle X$ and $\triangle Y$. Hence in any experiment both principal diameters should be measured and compared.

We may now look at an application. A steel pipe of 8 feet 4 inches mean diameter, made of $\frac{3}{16}$ inch plate, lying horizontally and free. What load per lineal foot may be placed upon it so that it shall be depressed not more than one-tenth of its diameter?

$E = 29{,}000{,}000.$	log. 7.46240
In one foot of length $I = \frac{bd^3}{12} = \left(\frac{3}{16}\right)^3$	" 7.81900
Radius R 50	" 1.69897
$\frac{EI}{R}$	" 3.58243

$\triangle Y = .10,\ B\quad .39955$		log. 9.60157
$\therefore M_B = B\dfrac{EI}{R}$	1527.6	" 3.18400
$\dfrac{Ee}{R} = \dfrac{3}{32} \cdot \dfrac{29,000,000}{50}$		" 4.73540
$\therefore p_B$	21726.	" 4.33697
$\dfrac{2EI}{R^2}$		" 2.18449
$\triangle Y = .10,\ K\quad .57913$		" 9.76277
$\therefore P$	88.565	" 1.94726

Therefore the load per lineal foot must not exceed 88.5 pounds, and this will cause a maximum fibre-stress (at B) of 21,726 pounds per square inch. Of course, if the pipe has side support, as of earth in a trench, or if the load were distributed, the load might be greatly increased with safety.



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THE CONTINUOUS RAIL IN STREET RAILWAY PRACTICE.

BY RICHARD MCCULLOCH, MEMBER OF THE ENGINEERS' CLUB OF ST. LOUIS.

[Read before the Club, October 2, 1895.*]

IN one of Jules Verne's stories there is very happily described the rivalry between an armor maker and a cannon manufacturer. Mix, forge, temper and chill as he would, no sooner would the armor maker turn out a piece of steel which was an absolutely safe covering for a war ship, than the cannon maker would produce a gun to shoot through it. Much the same condition of affairs might be supposed to exist between the rail-mill and the car-factory.

In the horse-car days, flat tram-rail, laid on stringers, was used almost entirely, and when the girder-rail was rolled it was supposed that all that could be desired in the way of track had been produced. But when electric cars were put on the horse-car tracks and when the length of these cars was increased from eighteen to thirty-five feet, the weights from five thousand to twenty-four thousand pounds, the speeds from eight to twenty miles per hour, and the headway decreased from five minutes to less than one minute, the rail manufacturer found himself a thorough sympathizer with Jules Verne's armor-plate maker. For every inch that he added to the depth of his girder-rail, and for every improvement in its manufacture, an additional length was added to the car and an additional weight to the trucks and motors.

* Manuscript received October 25, 1895.—*Secretary, Ass'n Eng. Socs.*

The life of a girder-rail is supposed to continue until the head becomes so worn that the flanges of the wheels begin to run on the tread. But as a matter of fact, few street railway tracks last until this takes place, for long before the head is worn off, the joints have become so rough that the rail must be renewed to save wear and tear on passengers and cars. No matter how carefully and skillfully the track has been laid, sooner or later the inevitable bump begins to notify the unhappy manager that his track is composed chiefly of joints. What to do is then a question. He may at quite an expense put a gang of men to work tightening up the fish-plates, shimming up the joints, putting stringers and steel plates underneath the rail ends, etc., but all this is necessarily slow and expensive work. Worst of all, it affords only temporary relief, for the very bump by which the joint first notified the world at large of its vitality, has flattened the ends of the rails so that the track is never again perfectly smooth at that point. This roughness soon starts the hammering action of the wheels and in a short time the joints again assert their presence. The Science of Invention has not been laggard in this problem, for the records of the Patent Office will show that not even the flying-machine or street-car fender has been a more popular subject than the invention of perfect joints.

Exactly who was the first man bold enough to suggest having no joints at all is hard to say, but it is pretty certain that the first experimenting in this line was done by Mr. Philip Noonan, a railroad engineer of Lynchburg, Va., who several years ago built about three miles of steam-railroad track leaving no openings between the rails and fastening the joints with hot-riveted plates. This track was in actual use for several years and was the first demonstration of the continuous rail. Early in 1892, the Johnson Company, of Johnstown, Pa., under the leadership of its president, Mr. A. J. Moxham, began experimenting with the continuous rail. One rail of a section of track 1,160 feet long, was joined by heavy bars and machine-fitted bolts so that there was no possibility of movement. Carefully fitted wedges were driven into the spaces between the ends of the rails, and every precaution taken to have the joint absolutely immovable. The other rail of the same track was laid in the ordinary manner with fish-plates and openings between the rails, so that any deviation of the continuous rail from a straight line would be noticed in the change of gauge. The rail used was the Johnson 6-inch, 78-pound girder, and the track was in actual use during the time of experimenting. At five points along the line, stakes were set opposite marks on the rails so that any change in the length of rail would at once be noticeable. Three times during the day and three times during the night, from March to September of 1892, temperature readings were taken of the following: air in the shade; road-bed at a

depth of seven inches; road-bed at a depth of ten inches; head of girder-rail and base of girder rail. Observations were also made at regular intervals of the position of the marks on the rails with reference to the stakes. Briefly summing up the result of the experiment, we may say that the temperature of the rail followed very closely the temperature of the air, being slightly colder than the air during the day and slightly warmer during the night. The road-bed, being a poorer conductor of heat than the rail, was less affected by the changes of temperature of the air. During the period of experiment, the air temperature varied from 10 to 89 degrees, and absolutely no movement could be detected in the rails, either longitudinally or laterally. This experiment satisfied the Johnson Company that the continuous rail was practicable; and having proved its feasibility they at once set about finding the best method of uniting the rail ends. This was the first thorough and scientific experimenting done in connection with continuous rails; and, whether or not the particular method of connecting the rail ends advocated by the Johnson Company is the best one, all honor is due the officers of this company for the contribution they have made to the knowledge on the subject and the unselfish manner in which they have disseminated it.

ELECTRIC WELDING.

The method adopted by this company for connecting the rail ends was that of welding them electrically. A machine for this purpose was built by the Thomson Welding Company, and in the spring and summer of 1893 about three miles in Johnstown and about eight miles of track in Boston were electrically welded. During the winter of 1893–94 about six per cent. of these joints broke. Having remedied some apparent defects in the method, the Johnson Company in the spring of 1894 sent their machine to St. Louis, where six and a half miles of track were electrically welded. From St. Louis the machine was sent to Cleveland, where about five miles were welded, and then to Brooklyn, where thirty-two miles of track were joined together by this method.

The first track electrically welded, that in Johnstown and Boston, was not welded directly at the joint, but the rail ends were joined on each side by means of a span which was welded to the web of the rail about four inches back of the end. The breaks did not occur at the joint or in the span, but the rail itself broke where the span had been welded on. This was supposed to be due to the fact that when the rail at this point cooled after the welding process, internal strains were produced which seriously impaired the tensile strength of the rail at this point. A new form of joint was devised by means of which an actual butt weld is made at the joint, and this is the method which has been applied in St. Louis.

The Baden Division of the St. Louis Railroad Co., where the electric welding in this city was done, consists of three and one-quarter miles of double track and extends from the northern end of the Broadway cable to the vine-clad hills of Baden, in the extreme northern part of the city. The track throughout is laid in a macadam street, no paving being used either inside or outside the rail.

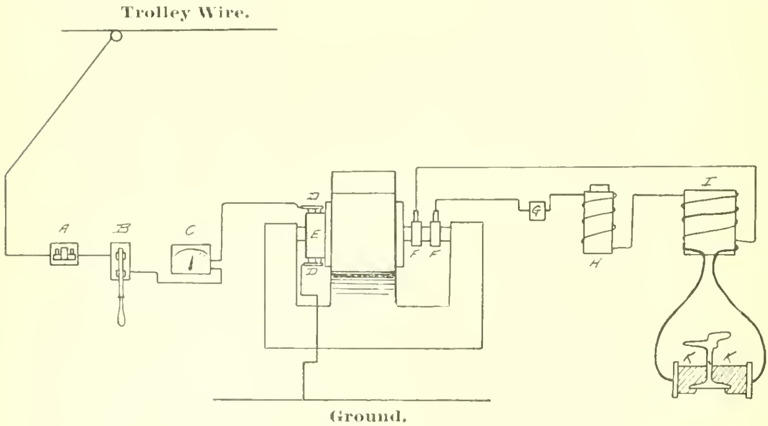

Fig. 1.—Diagram of Welding Circuit.

A Automatic Circuit Breaker.	*FF* Collector Rings.
B Switch.	*G* Break Switch.
C Ammeter.	*H* Reaction Coil.
DD Brushes.	*I* Welding Machine.
E Commutator.	*KK* Lugs for Welding.

A brief description of the welding apparatus will be given This is mounted on a car having its own motors and controlling apparatus, so that it may move along the track by means of the trolley current. For the welding, the current passes through an automatic circuit breaker, switch, ammeter and starting rheostat to a rotary transformer which converts from 500 volt continuous to alternating current. The transformer is an ordinary four-pole, General Electric, 100 kilowatt-dynamo. To obtain the alternating current four leads from the windings are taken off at equal distances around the armature and led to the two collector rings on the armature shaft. The speed of the transformer is about 1,100 revolutions per minute, so that the periodicity of the alternating current is about 4,400 per minute. The alternating current from the collector rings passes through a reaction coil with a movable iron core to the welding machine. This is on the end of the car and is hung on a crane so that it may be set over either rail. It works on the principle of the well-known Thomson welders, and is simply an alter-

nating current transformer on a large scale, in which the rail joint completes the secondary circuit. The insulation of the coils is paraffine oil and the secondary consists of an enormous bundle of sheet copper strips. These strips lead to two contact plates between which the welding is done. The distance between the plates is controlled by a toggle joint operated by a screw, so arranged that by a slight turn of the screw a great pressure may be brought to bear on the weld. In addition to this circuit, the welding car contains a motor for driving the crane and another which operates a pump for circulating water in the welding machine. The car is very heavy, weighing about thirty tons when equipped for work. The outfit also includes a small car which carries two motors operating emery wheels for polishing the joints, preparatory to welding.

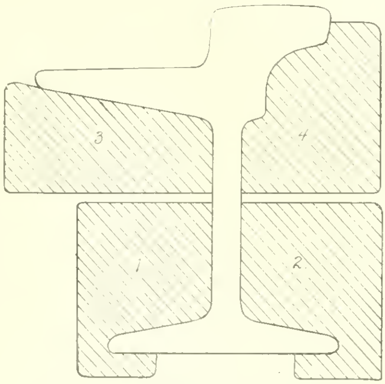

FIG. 2.—LUGS WELDED TO THE RAILS.

Nos. 1 and 2 welded at first heat. Nos. 3 and 4 welded at second heat.

The connection between the rail ends is made by lugs welded to the web of the rail. It is intended that enough plastic steel shall enter the joint to make a butt-weld, and that additional security is afforded by the lugs welded to the web. There are four lugs used at each joint and two welds are necessary, the bottom two being welded in one operation and the upper two in the next. During the welding operation, which lasts from one to two minutes, the direct current transformer takes from the line about 250 amperes at 500 volts. This is transformed down in the secondary of the welding machine to about four volts. The current which passes through the lugs on the rails is consequently 20,000 to 30,000 amperes.

The operation of welding is as follows: The ends of the rails are butted together by driving a wedge in the joint ahead, and the welding car is run over the joint to be welded, the welding taking place in the rear of the car, so that it is never necessary to run over a hot joint.

The webs of the rails are polished with emery wheels for about two inches to each side of their ends. The joint is clamped by means of a gun-metal casting, which holds the rails in proper position while the weld is being made, and the bottom lugs are then placed in position and

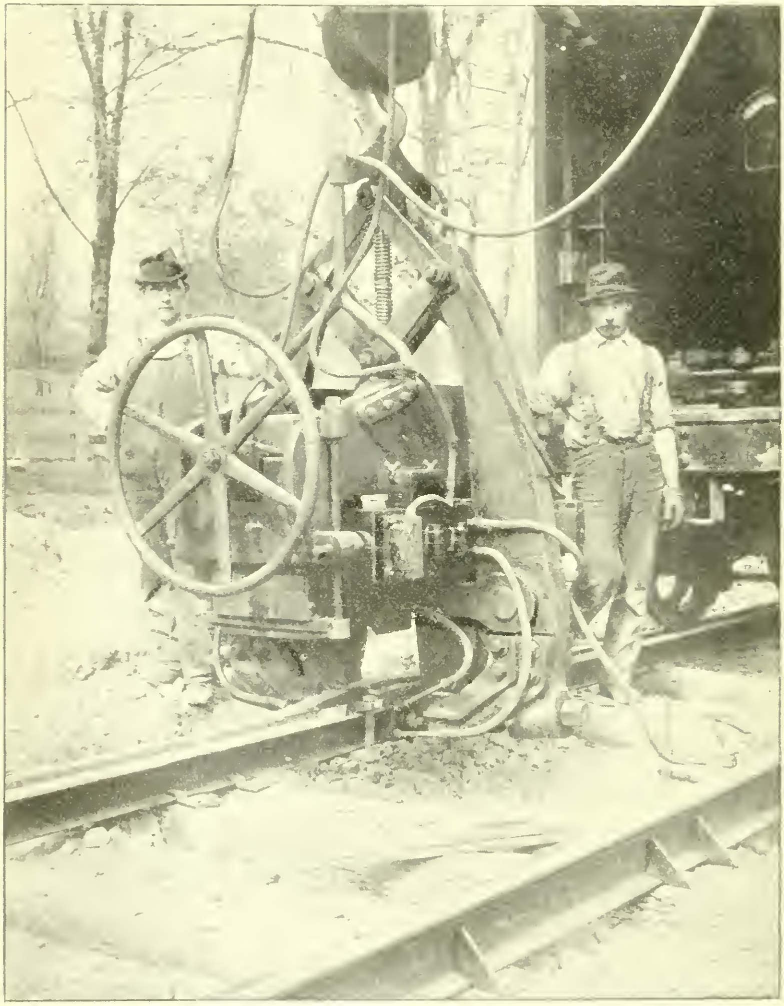

Fig. 3.

the contact clamps screwed down upon them. The circuit through the secondary winding of the welder being thus completed through the lugs, the switch of the welding machine is closed and the iron core of the reaction coil slowly raised. Almost instantly a dark, ruddy color

appears in the lugs which gradually brightens until the welding heat is reached. A quick turn of the screw which operates the toggle-joint brings the lugs firmly up against the rail and forces the plastic steel into the joint between the ends of the rails. The upper lugs are quickly

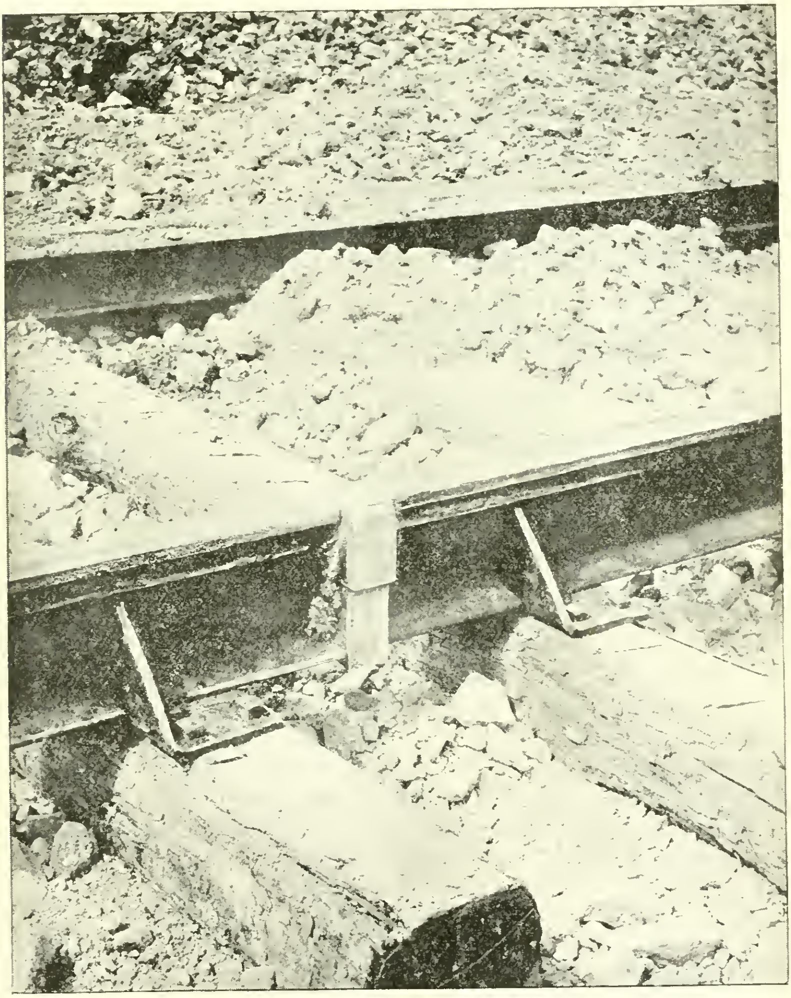

Fig. 4.

inserted, the contacts screwed down upon them and the welding performed in the same manner as in the case of the lower ones. A piece of carbon which has been placed on top of the rail before this operation, keeps this surface smooth and at the same time carbonizes and

hardens the rail at this point. As has been stated, from one to two minutes are consumed in making each weld, but the greater portion of the time is taken up in preparing the joints, moving the machine and setting up the welder. While in St. Louis, the machine completed thirty to fifty joints per day of ten hours.

Since this work has been done, the Johnson Company has built two more welding machines in which some improvements have been made. Instead of placing both the rotary transformer and the welding machine in one car, they are now put in separate cars connected electrically by cables. This makes the machine easier to handle, and distributes the weight over a greater distance on the track. A hydraulic jack has also been substituted for the toggle-joint used in forcing the lugs against the rails. The electric welding done by the Johnson Company in Brooklyn, after leaving St. Louis, was on nine-inch rail laid in paved streets. The track-work was entirely completed and paved up before any welding was done. When the machine arrived, the paving was taken up where necessary and the joints welded, leaving every third joint open. This was done in order to allow the rails to expand under the heat produced in welding. At night the welder was taken over the same track and this third joint welded.

CAST WELDING.

As soon as the fact was demonstrated that a continuous rail buried in the ground was a possibility, other methods besides the electric welding of the joints were proposed. The particular one which will be described here is what is known as the "cast-welding" process, and is being exploited by the Falk Manufacturing Co., of Milwaukee. This, to briefly describe it, consists of clasping the ends of the rails for about eight inches on each side of the joint by means of a mold, and then pouring the mold full of molten iron. The iron solidifies on the rails around the joints and makes a partial union with it.

In order to compare the two methods, the St. Louis Railroad Co., in the fall of 1894, had three miles of track in the southern part of the city connected by the cast-welded process. As the furnace was not ready at the time the rails were laid, the track-work was finished and the trench filled in, leaving the joints temporarily connected by fish-plates. Some three months later, when the furnace arrived, the macadam around the joints was dug up, the fish-plates removed and the rails united by means of the cast-joint. The track was laid in July and August and the rails were welded in October and November. No cars were operated over this track during the winter of 1894-95, but at present the cars of the Southwestern Railway are running regularly over this route.

On account of the excellent record made by this track during last winter, the officers of the Citizens' Railway Co. of this city decided, in relaying the old cable track, to use the cast-welded joint. As many new problems in street railway track construction have arisen during the progress of this work, a brief description of some of the methods employed may not prove uninteresting.

The Citizens' Railway, as all of you are aware, was built as a cable road nine years ago. The original cable track consisted of 9¾ miles of single track, and was laid with 4-inch, 52-pound Johnson girder-rail, which was the heaviest section rolled at that time. The rail was supported on cast-iron yokes, 4 feet apart, and imbedded in concrete. Last fall it was decided to operate the road by electricity, and on the 1st of January the cable power-house was shut down and the electric cars started. The rail adopted for the new track was 7-inch, 85-pound Johnson girder, to be delivered in lengths of 60 feet. Two special trussed wagons with wheel-bases of 45 feet were designed and built for the hauling of these rails. The curves were made of 6 inch, 97-pound girder rail, and all curves of less than 400 feet radius were designed with a spiral easement on each end, and were double guarded. Curves of 400 to 1,200 feet radius have a guard rail on the inside only, while those of still greater radius are sprung from the straight rails. As the new rail was three inches deeper than the old, it was impossible to lay it on the old yokes even if it had been advisable to do so. The ties are laid two feet between centers, and in order to make room for them and the 7-inch rail, it was necessary to take out about twelve inches of the solid concrete in which the yokes were imbedded, as well as to break off the yokes at this point. How to do this in the quickest and most economical manner possible was a problem. As it was necessary to abandon a portion of the road during construction, and as this line has a large passenger travel to take care of, speed in reconstruction was of the utmost importance. After quite a little experimenting, the plan of blasting out the concrete with dynamite was adopted. Two holes are drilled between each pair of yokes on each side of the track by means of a portable steam drill. An Ingersoll-Sergeant drill is used, and the steam is obtained from a 6-horse-power boiler placed in a car on the old track. Connection is made from the boiler to the drill by means of a steam hose. The holes are drilled as nearly as possible directly over the center of the block of concrete and are seven inches deep. The drill is operated from 5 A.M. to 9 P.M., by two shifts of men. The number of holes drilled per day varies from 300 to 700, according to the nature of the concrete. Each hole is loaded with one-tenth pound of 40° Ætna dynamite. Common sand is used for tamping, and from eight to twelve holes are fired at once by means of a magneto. In order to

prevent all danger from flying particles, an old car especially prepared for this purpose is placed over the holes before shooting. This car has been strongly braced and floored with ties, and is provided with heavy sideboards which are lowered before firing, thus forming a completely closed space over the charge. Blasting with this outfit has been done in the narrowest streets in the heart of the city, and up to this date no accident of any kind has occurred. Considerable experimenting was done in order to find out how deep to drill the holes and how much dynamite to use. The quantity adopted will just shatter the top of the concrete so that it may be picked out in large pieces, leaving the con-

Fig. 5.

crete unbroken twelve inches below the surface, thus affording a solid and substantial foundation for the ties. The bottom of the conduit is filled with fine, broken concrete, washed in and thoroughly rammed before the ties are laid in the trench. Having prepared the road-bed in this manner, there remains beneath the ties a solid block of unbroken concrete of the width of the track and over two feet in thickness.

After excavating the trench the track is laid, joined together temporarily by fish-plates, tamped, lined, surfaced and completely finished in every particular before the joints are cast. The apparatus

for casting the joints consists of a cupola furnace mounted on a heavy truck. The cupola is two feet in diameter, brick lined, and the blast is furnished by a No. 5 Sturtevant blower, driven at 1,800 revolutions per minute, by a 5-horse-power motor, which receives its current from the trolley. The cupola is operated as is usual in a foundry, and the iron used is one-half best soft gray pig and one-half selected scrap. The scrap consists of old gear wheels, man-hole covers and frames, an abundance of which are found in the scrap heap of the railway. The furnace works very rapidly, and in twenty minutes after the blast is turned on the iron is ready to pour. It may then be tapped as long as the charging is continued at the top. As the machine

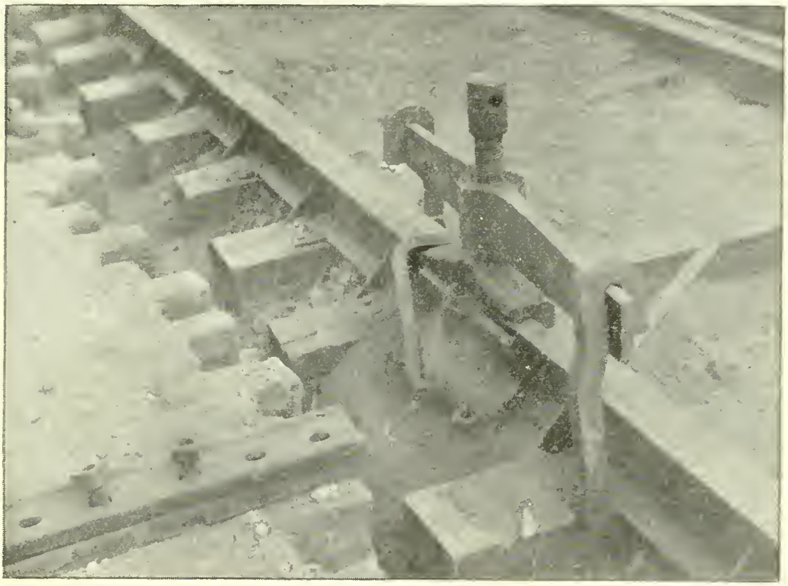

FIG. 6.

has been operated on the Citizens' Railway about 1,200 feet of the track has been prepared, and all the joints molded in one heat. As many as 72 joints have been poured at one melting, and it is probable that 90 or 100 could be made before shutting down the furnace to renew the lining.

The preparation of the joint for casting is as follows: The fish-plates are first taken off and the rail-ends for about eight inches back polished with garnet paper. If there is any opening between the rails it is closed by shims. The molds, consisting of two castings made to fit the rail, are then placed about the joint and clamped in position. A

heavy clamp is placed on top of the rail and screwed up as tightly as possible, to hold the joint immovable while being poured. This clamp is left on the rail until the casting has cooled. Preparatory to the pouring, the molds are lined with a mixture of linseed oil and plumbago and heated to drive out any moisture in them or on the rail. The pouring operation is very simple. The melted iron is run from the cupola into a ladle and then slowly poured into the mold. This final operation is very quickly performed, as it usually takes only about three hours to pour forty joints. The casting weighs 137 pounds and extends back on the rail seven inches, taking in two of the bolt holes in the ends of the rails. In this way four bolts are cast through the rail. It is

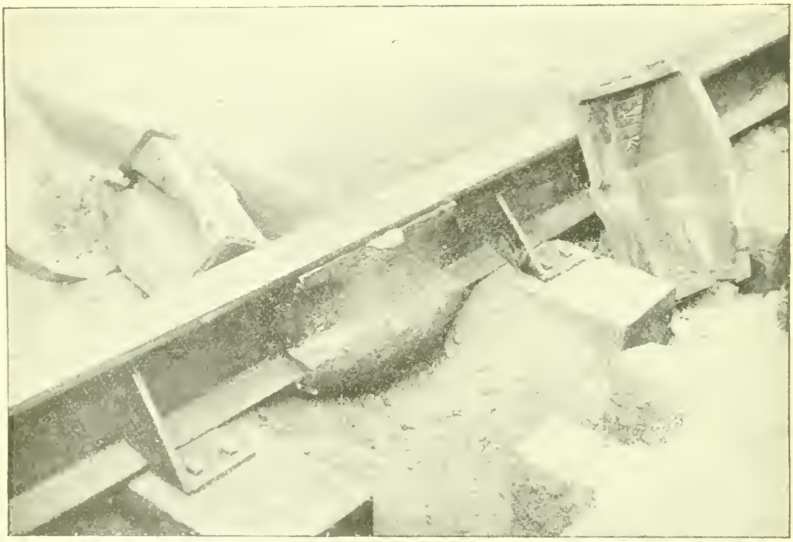

Fig. 7.

undoubtedly the case that a sort of welding action takes place between the iron and the steel rail, as on examination of a joint sawed in two it will be difficult to tell the exact junction of the iron and steel.

RESULTS OF EXPERIMENTS.

Having described the modes of applying these two processes, let us see what they have done in actual operation. The Baden Road, constructed in the spring of 1894, which had its rail-ends connected by the electric method, had in all 2,203 joints, and of these 72, or 3.27 per cent., have broken. Thirty-seven broke during the cold weather of the first part of the winter, and these were repaired by the cast-welding method.

During a later cold snap thirty-five more were broken. These have not yet been repaired. During the heat of the summer no trouble whatever was experienced with alignment of the track. From the Weather Bureau reports the average temperature, while the construction was in progress, was 63 degrees, ranging from 14 degrees as a minimum to 99 degrees as a maximum. During the last winter the lowest temperature was 12 degrees below zero and the hottest day in the summer was 100 degrees, making the range of temperature through which the track has passed 112 degrees, or a maximum deviation from the average welding temperature of 75 degrees. Several of the joints on breaking opened nearly two inches, but in many the opening was so small as barely to be perceptible, the average opening being about one-quarter of an inch. During the warm weather of this summer the openings were diminished slightly, but the joints have never completely closed. Every joint which has broken has shown itself to be an imperfect weld. There has never yet been an instance of a good weld breaking. In all cases, the rail-ends have simply pulled apart, the lugs sticking to that rail which held them tightest. In a few instances small pieces of rail pulled off with the lugs, but in no cases have the rails themselves broken and we have never had a joint to break which looked as if it had ever been really welded. There are several reasons for this. On account of the great distance from the power-house, the voltage was necessarily low while the weld was being made. The work at that time was new and not very well understood, and the workmen who had the machine in charge were often careless and hurried. The result of this experiment is far from being discouraging, and the officers of the railroad company are satisfied that with the additional knowledge we now possess, and with the improvements which have been made in the welding machine, by which a fairly constant voltage is maintained while the welding is in progress, that it is possible to construct a track by this method with an insignificant trouble from breakage.

In regard to experiments elsewhere, Mr. C. W. Wason, Electrical Engineer of the Cleveland Electric Railway Company, has been kind enough to furnish information as to the results obtained in Cleveland. During the summer of 1894, 3,400 joints were made electrically, two-thirds of which were on 56-pound rail and the remainder on 90-pound rail. Of this number, the total breakage during last winter was six, four of them being on 56-pound rail and the remainder on 90-pound rail. The percentage of breakage was 0.18 per cent., which is a much better record than that made in St. Louis. All the joints which broke showed themselves to be imperfectly welded. Mr. Wason expresses himself as highly in favor of the electric method of welding, and states that the breaks and rough joints on his track were due to carelessness on the part of the workmen operating the machine.

The cast-welded track of the Southwestern Railway on Chippewa Street was welded during the months of October and November of the same year. The average temperature while this work was in progress was 51 degrees, with a maximum of 84 degrees and a minimum of 18 degrees. There were 744 joints in all, and during the winter only three, or 0.43 per cent., broke. As stated in the case of electric-welded track, no deviation whatever has been perceived in the alignment. Since this track was laid, the temperature has ranged from 100 degrees as a maximum to 12 degrees below zero as a minimum, a range of 112 degrees and a maximum deviation of 63 degrees from the welding temperature.

The Falk Manufacturing Company, who are making the cast joint, have this summer operated in Chicago, St. Paul, Minneapolis and Newark, besides the work done in St. Louis. In Chicago, for the Chicago City Railway, 11,903 joints were made on 4½- and 7-inch rail, and for the West Chicago Street Railway Company, 8,867 joints were made. In St. Paul, Minneapolis and Newark, work has recently begun, and up to the present time about 2,000 joints have been made in each place. The results so far have been very satisfactory both to the railroad companies and to the contractors.

It seems difficult to those accustomed to steam-railroad tracks to reconcile themselves to the use of a continuous rail. They instinctively call to mind certain experiences they have had with rails creeping and getting out of place on account of temperature variations. It must be remembered, however, that street railway tracks differ in one very important particular from those of the steam railways, that is in having a road-bed firmly packed about the rail. The perimeter of a 7-inch rail is 29 inches, of which only 6½, or 22.4 per cent., is exposed to the air, while the remaining 67.6 per cent. is covered up and firmly gripped by the road-bed. No one can understand how firm this grip is, who has not seen a rail which has lain in a macadam street several years taken up, when the whole buried surface of the rail is found to be covered with a hard cement composed of stones and mud, requiring considerable work with a pick to remove. There is a great tendency on the part of the rail to change its length with the temperature variations, but there is also the ability of the road-bed to hold it in place.

CALCULATION OF STRAINS.

The strain on rails due to the variations of temperature, may be estimated as follows. Assuming a coefficient of expansion for steel of 0.0000065, and multiplying this by 75, which is a liberal figure for the number of degrees of maximum deviation from the welding temperature, we get 0.000487, which is that part of its length which a rail

would expand, due to a rise of 75 degrees, or contract, due to a fall of 75 degrees in temperature. A steel bar will expand 0.00003 of its length, due to a load of 1,000 pounds per square inch. Dividing the estimated expansion by this figure, we get for the strain, 16,200 pounds per square inch. As the rail is $8\frac{1}{2}$ inches in cross-section, the total pull, due to a fall of 75 degrees in temperature, is 137,700 pounds.

As 40,000 pounds per square inch is a safe value for the elastic limit of steel, it can readily be seen that, in this climate at least, the elastic limit will never be reached ; and this means that these expansions and contractions may go on indefinitely, and as long as the joints remain unbroken, no harm will be done to the rail, for it is a well-proven fact that stresses within the elastic limit work no harm.

Assuming 80,000 pounds per square inch as the ultimate strength of steel, we see that, so far as the strength of the rails themselves is concerned, we have a factor of safety of five.

An interesting calculation may be made, showing the friction with which the rail is held by the road-bed. Taking the figures for the contraction of the rail due to a fall of 75 degrees in temperature, each rail of the Baden track should have contracted 8 feet 6 inches. As a matter of fact, when the joints broke, the openings in none of these exceeded 2 inches, and the combined openings of one rail the length of the road did not exceed 6 inches. This would seem to show that the pull which broke the joint was not a transmitted, cumulative effort, extending all along the line, but was more the result of a local strain, not extending for a great distance on either side of the joint. Reasoning from the same data, it would appear that the strain at other points along the track has not been relieved, and that the joints at these other places have shown themselves strong enough to endure the pull.

The strength of the cast-iron joint may be shown to be fully equal to the strength of the rail. The area of its cross-section at the joint is 61.6 square inches. In order to make a perfectly safe estimate, let us assume that its cross-section is reduced 25 per cent., or to 45 square inches by blow-holes and imperfections. Taking for the tensile strength of cast-iron 18,000 pounds per square inch, we have as the ultimate strength of the joint 810,000 pounds, which is largely in excess of the strength of the rail.

COMPARISON OF METHODS.

The two methods just described are the only processes of actually welding rails yet put into operation. The electric welding is scientifically a beautiful process, and when skillfully done, we have no hesitation in saying that the joint is stronger than the rail itself. It has the disadvantage, however, of requiring considerable care and intelligence

to operate it, qualifications which are sometimes difficult to find in workmen. It is also impossible to tell, simply by looking at a joint, whether or not it is really welded. On ordinary railway circuits when the voltage fluctuates continually, it is difficult to operate the process successfully. This, however, it is proposed to remedy by using a storage battery, which takes current from the line when the welding machine is idle, but which is thrown into parallel with the line, and assists in maintaining the voltage while the welding is in progress. The welding machine, with its accessories, is exceedingly heavy and cumbersome, and difficult to move from place to place where track is not already laid. The great expense of an outfit prohibits almost any railroad company owning one, and this complicates the question of repairs, for, if the machine is gone and some of the joints break, how are they to be repaired?

Without wishing to make any invidious comparisons, it would be well to call attention to some of the advantages which the cast-welding process possesses. The first is the relative simplicity and cheapness of the apparatus employed, and the ease with which men may be procured who are used to this kind of work and capable of doing it well. The machine is not very heavy, it does not run on the track and can be transported easily and quickly from place to place. While as yet no difficulties have developed, the weak points of the process would seem to be: first, that the joint is a casting, subject to blowholes, chilling, imperfections and all the ills of a casting, any one of which might greatly impair its tensile strength; and second, the fact that the steel-rail and the cast-iron joint possess different coefficients of expansion, and that, under variations in temperature, internal strains might arise in the joint itself, which might finally result in its rupture. As has already been stated, however, no troubles of this kind have as yet developed, and these are merely considerations which suggest themselves in the examination of the process.

The cost of either of these methods is not greatly in excess of the old fish-plate method, but even if it was, the advantages gained by the abolition of joints would be of such value that no progressive railroad man would hesitate on that account. If either method will remedy for all time trouble with joints, the cost of repairs to the track, after being down a few years if laid with fish-plates, would soon pay the extra first cost, without considering the prolonged life of the rolling stock and the prestige given to the road on account of its smooth riding track. If joints are abolished, the life of a track, instead of being limited by the life of the joints, will be the life of the rail itself, and this will far outweigh any considerations as to the cost of making the joints.

An additional advantage which should be mentioned is that any

form of welding obviates the necessity of bonding the joints of electric roads. Tests which have been made on welded joints show that the electric conductivity of the joint is as great as that of the rail itself. Assuming the conductivity of steel to be one-seventh that of copper, an 85-pound steel rail would have a carrying capacity equal to a copper bar 1.2 square inches in section, or, as feed-wire is usually rated, of 1,500,000 circular mils. A double track, consisting of four of these rails, would thus have a conductivity equal to 6,000,000 circular mils. This is largely in excess of the feeder section of any one line of railway in St. Louis. For instance, the combined section of the feeders which run to the Citizens' line, which was calculated for 60 cars, allowing a drop of 50 volts at full load, is 3,200,000 circular mils. To one who is engaged in the actual operation of street railways this means a great deal. Given a track with a conductivity equal to that just cited, it is necessary only to establish a low resistance connection between the rails and the buss-bar in the power-house, when all the troubles due to a low voltage along the line, and all the dangers of electrolysis would be a thing of the past.

It is not to be supposed that the millennium in track construction has already been reached, but what has been demonstrated is this: first, that the use of a continuous rail for street railway practice is feasible; and second, that it is possible to make joints of sufficient strength to stand changes of temperature. Whether new difficulties will develop remains for the future to show, but let us hope that those of us who have placed our faith in rail-welding will not share the fate of Jules Verne's armor-maker, who planned, mixed, forged and tempered his best, only to see the triumph of his skill shot to pieces by the latest gun of his hated rival.

A STUDY OF THE HEATING AND VENTILATING PLANTS IN THE SUFFOLK COUNTY COURT HOUSE AND THE MASSACHUSETTS STATE HOUSE, BOSTON.

By Percy N. Kenway, Member of the Boston Society of Civil Engineers.

[Read before the Society, September 18, 1895.*]

These two buildings are so nearly alike as regards size, exposure and conditions of use, that a study of their heating and ventilating equipments and some of the results obtained, will, I hope, prove not uninteresting.

But while the buildings are so nearly similar, the heating plants differ from each other very radically and at very many points, both in general design and in detail; in fact, there is hardly a single feature which is common to both.

In each case the selected engineer was in consultation with the architect while the building plans were being prepared, and his suggestions were followed wherever practicable, though in the case of the Court House some progress had been made on the foundations before such consultation, so that the engineers were at a disadvantage. In both buildings the uses to which the different rooms were originally assigned were in some instances changed, during or after construction.

I will first call your attention to the ground plans of the two buildings which are shown in outline, Figs. 1 and 2, on the same scale, and from which you will readily see that the area covered by each of the buildings is somewhat alike. The State House, however, is actu-

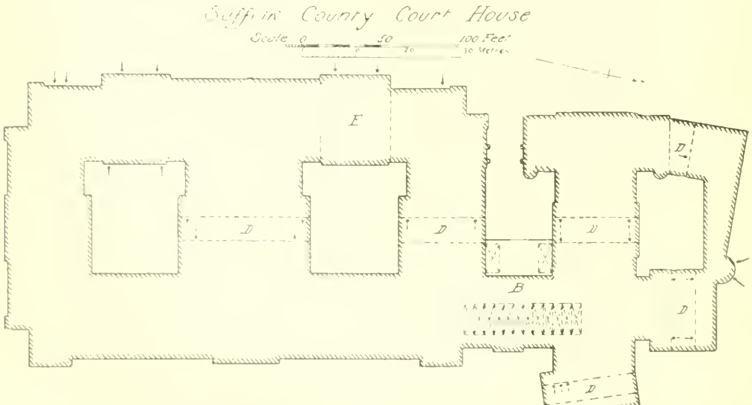

Fig. 1.

* Manuscript received October 31, 1895.—*Secretary, Ass'n of Eng. Socs.*

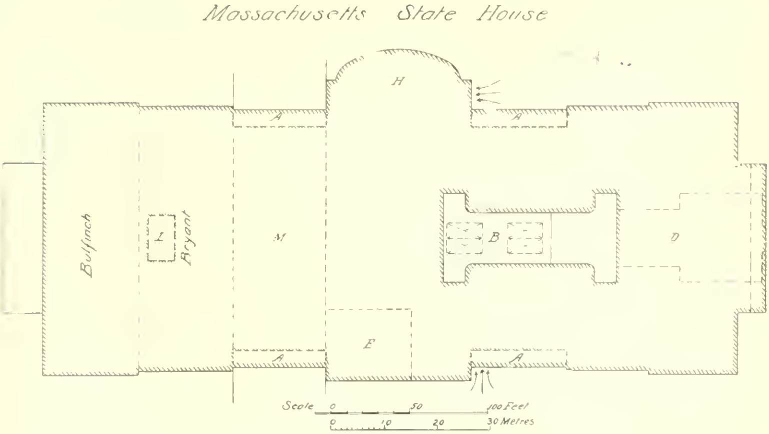

Fig. 2.

ally the larger of the two, careful computation giving the figures in Table I.

Table I.

	Court House.	State House without Bulfinch Portion.
Cubic capacity	5,500,000 cubic feet,	6,200,000 cubic feet.
Area covered	65,300 square feet,	67,000 square feet.
Heating surface—direct	35,800 "	15,000 "
Heating surface—indirect . . .	67,000 "	9,560 "
Total heating surface	102,800 "	24,560 "
Cost of building	$2,700,000	$3,000,000
Cost of apparatus	$122,000	$112,000 *

* This includes $6,000 for temporary apparatus for drying the building, and $4,800 for air filters.

For the purpose of this paper we will leave out the Bulfinch portion of the State House, shown at the extreme left of the plan. This is the original building, erected in 1798, the proposed destruction of which has recently brought out such strong protests from many good citizens of Boston. A steam heating plant was installed in this building in 1867, and has since been modified—the original fan for the ventilation of the House and Senate Chamber being replaced by one of more modern type about fifteen years ago.

The Bryant addition, on the north side of the Bulfinch building, was built in 1855, and has now been pulled down and is being rebuilt in conformity with the design of the "Extension." Mount Vernon Street runs under the portion marked M, which, in consequence, has no basement or first floor.

The wing at the right, on the Court House plan, is the Municipal Building, and contains the City Prison and the Criminal Court rooms. The remainder is the County building, devoted to Court rooms, rooms for judges, lawyers and juries, and the Law Library, which occupies nearly the whole of the front of the building on the third floor.

The heating and ventilation of the Court House is accomplished by a hot-water apparatus, operating without pressure except that due to the head of water in the system. The boilers are placed below the lowest radiating surface, special excavation (which on account of the foundations being already in place, was very costly) having been made for this purpose. *B* on the plan indicates the boiler room. The water being heated in the boilers to a temperature varying according to the weather, from 80 to 180 degrees, flows through the supply mains and their many branches, rising till it reaches the various radiators, in which it is cooled, and then flows back through the return pipes into the boilers again—without the intervention of any traps, tanks or pumps—arriving at a temperature averaging 15 degrees cooler than when it began its journey. The usual expansion tank is provided at the top of the building, and the water level in this tank is maintained automatically. The air-vents of all the indirect radiators are connected to two 1½-inch mains, which are run to the top of the building and have a free discharge. The direct radiators are provided with ordinary air cocks

The rooms are warmed partly by passing the air supplied to them through large return bend-coils of 3-inch cast-iron pipe placed in brick chambers at the base of the several flues, and partly by horizontal wrought-iron tube radiators located in the window recesses.

Ventilation is effected without the use of any moving machinery. The tunnels or corridors in the sub-basement which contain the large hot-water pipes serve also as main fresh-air ducts to those rooms which can be reached from them. The Court rooms have, as a rule, independent fresh-air inlets.

The air inlets to the rooms are, in most cases, on the warm or inner side, and are placed at the floor. All the Court rooms, however, have two opposite exposed sides, and in these cases there is an air inlet at each corner on one exposed side, and a corresponding outlet flue on each corner on the opposite side (as shown in Fig. 6). The outlet flues have registers both at the ceiling and at the floor. With this arrangement of air inlet and with no means for diffusing the air as it enters, it is not surprising that when weather conditions are favorable, and the volume of entering air large and its velocity consequently high, drafts are complained of by persons sitting near the supply registers. To avoid these, screens or baffling plates have, in some cases, been provided, and

in some cases the inlets have been raised a few feet above the floor. The efficiency of the air circulation in a room so arranged is evidently open to grave suspicion, for it is obvious that as regards the two exposed sides it cannot possibly be symmetrical. The entering air, being warmer than the air of the room, a large proportion of it—especially where the screens are used—will rise immediately to the ceiling and then gradually

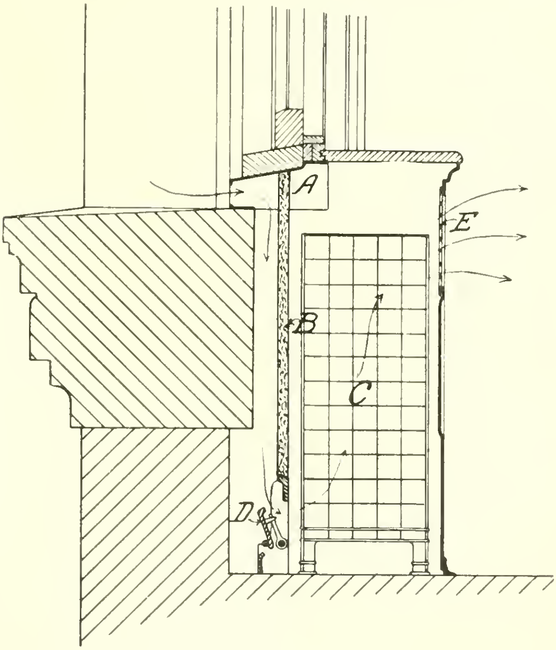

Fig. 3.

find its way down the cooling surface of the windows towards the floor. That portion of it which flows down on the side where the inlets are placed, will have to cross the room to the outlets at a low level and will do useful work, but that which comes down on the other side can reach the outlets almost without working its passage, and except for the foul air at the ceiling—which doubtless it does help to dilute and displace—it would be almost as pure when it left the room as when it entered it.

The temperature in the rooms is regulated very approximately by the temperature of the water in the main supply pipe—a thermometer being placed in this pipe for the guidance of the engineer, who varies the condition of his fires and the number of boilers used, according to the outside weather. A further regulation in any particular room is effected by operating the valves of the direct radiators under the

windows, or by changing the position of the mixing dampers which are provided for all the Court rooms.

It was prophesied before the apparatus was completed, that a large corps of supernumerary engineers would be needed to regulate with every change in the weather, the many valves and dampers which form a part of the apparatus. This, however, does not prove to be the case; in the Court rooms the mixing dampers are rarely touched except when something of unusual interest is going on, and the room is consequently crowded. Then the adjustment is usually made by one of the two engineers. In the smaller private rooms the radiator valves and cold-air dampers are controlled by the occupants, while in the jury and other rooms—which have no air-supply flues, and are not occupied constantly by the same persons—the valve wheels have, in most cases, been removed as a safeguard, and the temperature of such rooms is dependent on that in the apparatus and on the amount of air admitted behind the radiators.

The ability to approximately regulate the temperature in such a large building from a central source is undoubtedly one of the strongest arguments in favor of a hot-water apparatus as against steam. A range of temperature extending over more than 100 degrees Fahrenheit is at the disposal of the engineer, without in any way straining the apparatus or increasing the pressure, whereas a pressure of about 70 pounds per square inch would be needed in the case of steam to get an additional 100 degrees over the temperature at the boiling point, and such a pressure in a large apparatus, with many thousands of joints and fittings and some miles of piping, would be impracticable and even dangerous.

There are in the Court House about 220 occupied rooms, including the large Law Library and some twenty other very large rooms used as court rooms or rooms for hearings, but not counting toilet rooms. The Law Library has a cubic capacity of about 132,000 feet, and the other large rooms average nearly 40,000 feet each. About twenty of these two hundred rooms are used for unimportant purposes and have direct radiation only, without air supply. Ninety of them have direct radiators in the window recesses, enclosed in cast-iron casings and arranged to warm air taken from the outside through cast-iron subsills, as shown in Fig. 3. *A* is the subsill; *B* an apron of 1 inch hair felt, cased in galvanized iron, extending across the window recess; *C* is the radiator; *D* a damper for admitting air behind the radiator, and *E* the grating through which the air escapes into the room. The dampers are under the control of the occupants of the rooms, and, as a matter of fact, in cold weather most of them are closed, the occupants preferring to have them so. These rooms all have vent-flue connections, but no air supply other than that admitted through the dampers *D*, so that, with these dampers

closed, the ventilation cannot be very excellent. However, in most of these rooms the number of occupants is small and a large supply of air is not needed.

The remaining one hundred and ten rooms have both air supply and vent-flue connections, in addition to direct radiators in the window recesses. These radiators, however, have no subsill air supply, but are simply enclosed in cast-iron screen work, with gratings at the top and bottom for the circulation of air.

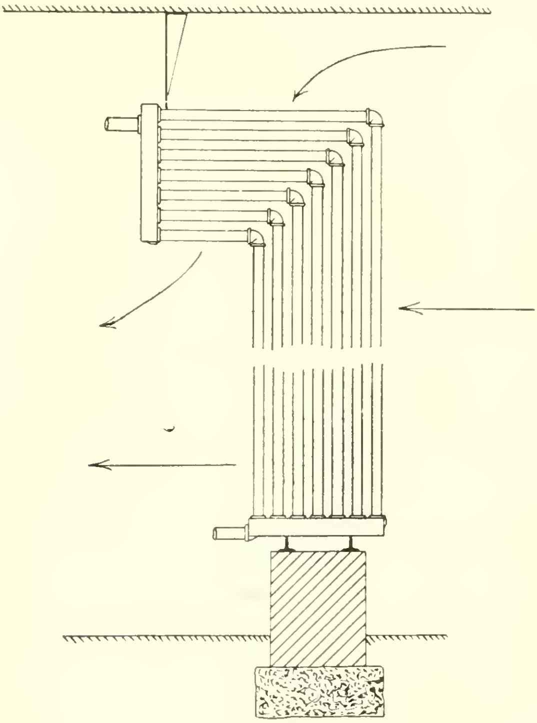

FIG. 4.

The corridors and hallways are warmed by indirect radiation, without air supply from the outside. An air connection is made from the floor of the hall, or corridor, to the underside of indirect stack, and another connection from the top of the stack to the floor again, or to a register in the wall above the floor. In this way these spaces are warmed by circulating the air contained in them through the indirect radiators.

The amount of air supplied with this, as with any gravity ventilating apparatus, is dependent, first, on the difference between the inside and outside temperatures; second, on the direction and force of the wind; third, on the barometric pressure; fourth, on the amount of heat

used in the aspirating coils in the vent shafts, and fifth, on the area height and form of the supply and vent flues and their freedom from obstructions and changes of direction. From this it will be seen that the air supply in this building is not likely to be constant, but must, of necessity, vary from day to day with the outside weather conditions. The severest test for such an apparatus is a spring or autumn day when the barometer is low, the air still and the temperature a few degrees too cool for open windows. If the amount of air supplied on such a day is up to the standard, then of course it would be theoretically possible to keep the supply constant, and to have neither more nor less air than is needed at any time; but as this would entail, in the case of the Court House, the very frequent, perhaps hourly, manipulation of seventy-four cold-air dampers, it would hardly be practicable, and as a matter of fact it is not attempted, although the dampers are used to check the flow of air to the rooms when it becomes too generous under favorable weather conditions.

Turning now to the State House, we find there a steam apparatus throughout. A pressure of 100 pounds per square inch is carried on the boilers for the purpose of running the engines in connection with the electric lighting plant, but only from two to ten pounds is used in the heating apparatus. The boiler room is located in the courtyard of the extension—as shown at *B* on the plan—and its floor is about two feet below the level of the sub-basement. It is a one-story structure, the roof being largely of glass, making it an exceptionally light room.

The different pressures carried and the high pressure needed for the engines made a gravity apparatus impracticable in this case, and consequently the water of condensation from all the direct radiators and from the main coils—with the exception of the exhaust steam sections—is returned to the boilers through a series of traps, tanks and pumps. The rooms here, as in the Court House, are warmed partly by the air supply and partly by direct radiation; but in this case the indirect radiation, instead of being divided up and placed at the bases of the several flues, is massed in large stacks near the main air inlets. The two sets of stacks, through which passes all the air supplied to the extension (the whole building except the Bulfinch and Bryant portions), are built of 1-inch wrought-iron pipe, and are made up of a series of miter coils set up on end and connected together in sections. The arrangement will be better understood by referring to Fig. 4, which shows one of the coils and its relation to the floor and ceiling. The largest stack contains ninety of these coils, connected together in groups of ten, each group having separate controlling valves.

Ventilation is effected by fans driven by electric motors, and for this purpose the extension is divided into two sections, the Bulfinch

and Bryant portions together making a third, so that there are three supply fans and three sets of main coils. The general method of ventilation can be understood from a description of the apparatus on the west side, which is the more interesting as it supplies air to the House of Representatives. The air inlet is on the west side, and is indicated by arrows on the plan. On its way to the fan the air first passes through a series of primary coils, which are designed to heat it to about 40 degrees in zero weather. Between these coils and the fan there is a large chamber in which it was designed to place an air filter; but this has not as yet been constructed. The fan is 12 feet diameter and 14 inches wide

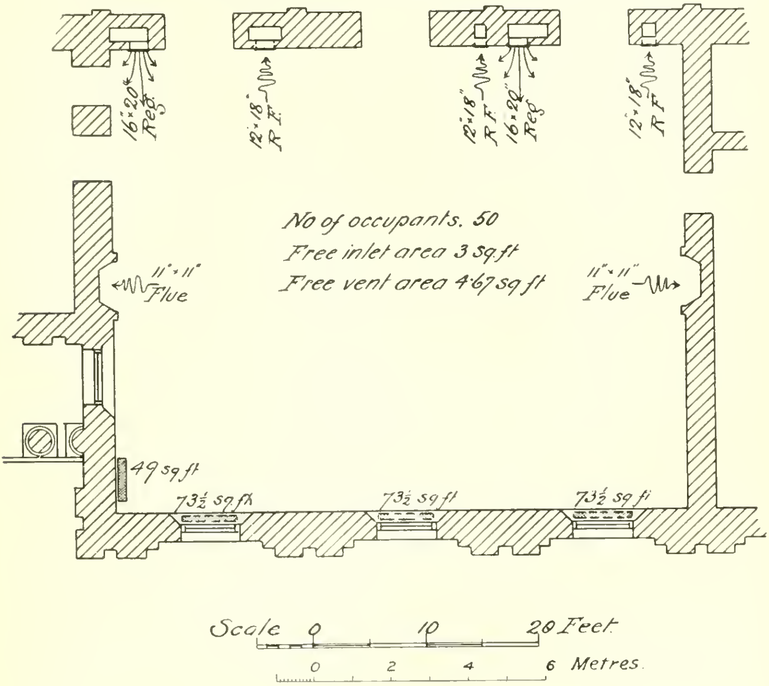

Fig. 5.

at the tip of the blades. It is a cone fan of the Briggs-Meigs type, modified by Prof. Woodbridge, and has proved very efficient and economical of power. The one on the east side is of the same type, but two feet less in diameter, as it has less work to do.

After passing through the fan the air is forced through a secondary coil, and is further heated to about 75 degrees, at which temperature it is distributed through the vertical ducts to the different floors. The total area of the main air supply ducts on this side is 145 square feet, 45 square feet being for the House of Representatives. Horizontal

branches are taken out of the vertical ducts at each floor for the purpose of distributing the air to the rooms. These horizontal ducts are formed by furring down the ceilings of the corridors, so that they are not visible, and by the casual observer would be unsuspected. The air inlets to the rooms are in most cases taken directly out of these corridor ducts, so that they are on the inner side of the rooms and usually something less than three feet below the ceiling. The vent outlets are, in nearly all cases, at the floor, and, wherever practicable, on the warm side, and are furnished with gossamer check valves to prevent down-drafts. No ceiling outlets are provided and the floor outlets have no register valves. Some of the rooms which could not be reached from the corridors have separate air-flues leading up from the sub-basement, and connected to the warm air chamber by galvanized iron piping. In these rooms the air inlets are about eight feet above the floor.

The House of Representatives, the location of which is indicated by the letter *H* on the plan, is elliptical in form, 86 feet long by 70 feet wide and 44 feet high, has a cubic capacity of about 264,000 feet and seats 240 persons on the floor and about 200 in the galleries. On special occasions, when the standing room is occupied, as many as 1,800 persons may be inside the doors at one time. This chamber is treated in a special manner, the conditions being different to those existing in the other rooms. A special vertical air-duct is provided, which has two openings at the base, both connecting with the air-pressure chamber, but one connecting on the inside and the other on the outside of the secondary coil, so that air at 40 or at 75 degrees, or at any intermediate temperature, as required, may be supplied. Mixing dampers, automatically controlled by thermostats, are provided in front of the openings and keep the temperature of this important legislative chamber practically constant, in spite of variations in the weather and in the number of occupants. The air-inlets to this room are differently arranged to those in the other rooms. The desks on the floor and the seats in the galleries are fixtures, and the floors are raised and inclined in such a manner as to give a considerable air space between them and the ceilings below. Into these spaces the air from the vertical duct before mentioned is discharged, so that they become air-pressure chambers. The desks are of special construction and have hollow bases which connect with the air chamber below, and the air finds its way into the room through gratings (backed by coarse haircloth) in these bases and in the risers of the floor, which is stepped. The gallery inlets are somewhat differently arranged, though the same principle of a large and evenly distributed inlet area near the floor and a low velocity of air flow is carried out. The total area of inlet is about 240 square feet for the floor and 200 square feet for the galleries, or one square foot for each regular occupant.

The main vent outlet is at the ceiling, where a free area of about 20 square feet is provided, but there are also 16 square feet of outlet area in the rear walls for the galleries. The ordinary air supply to the House is 900,000 cubic feet per hour, but it has been found quite possible on special occasions to raise it to 1,300,000, and that without causing disagreeable drafts. Samples of air taken at the ceiling ventilator towards the close of the exercises on the occasion of the Governor's inauguration last January, when fully 1,800 persons were inside the

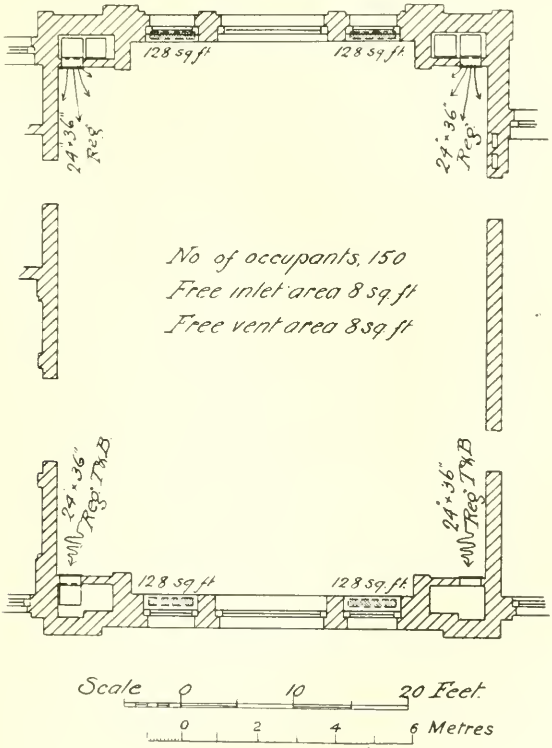

FIG. 6.

doors—more than four times the seating capacity—gave by the Pettenkoffer method 12.1 parts of carbon-dioxide in 10,000—a large proportion under ordinary circumstances, but a very satisfactory showing considering the adverse conditions and the fact that the samples were taken at the point of maximum impurity. It may be mentioned incidentally that a Wolpert air tester, carefully used at the same time and place, gave but 8¼ parts CO_2 in 10,000, indicating an error in the latter instrument of more than 30 per cent. As the Wolpert device is used by the District Police in testing the air in the schoolhouses of this State, this fact has some significance.

The warming of the House is done entirely by the air supply, no direct radiators being used. The temperature of the incoming air, when the room is occupied, rarely exceeds 70 degrees in the coldest weather.

The temperature of the air supply and of the rooms and corridors throughout the building, is automatically controlled and kept constant within one or two degrees by the Johnson Electric System, so long as the weather is cold enough for artificial heat to be required. Thermostats are placed in the main air ducts and control sections of the main coils, and in each of the rooms and in the corridors there are other thermostats controlling the valves on the direct radiators. The mixing dampers above mentioned, which regulate the temperature of the air to the House, are also controlled by the Johnson System. *No valves or dampers are accessible to the ordinary occupants of the building, or need to be operated or thought of by them.*

In the completed building there will be about 200 occupied rooms, including the House of Representatives, the State Library and the Senate Chamber. Of these, 170 will have connection to air supply and vent flues as well as direct radiation. The remaining thirty include such rooms as the restaurant and kitchen, and the Board of Health laboratories on the fifth floor, which have liberal vent connections, but take their air supply from the hallways and corridors; and the stack rooms, on the third floor, through which the air from the State Library passes on its way to the vent outlets. The advantages and economy of such an arrangement are obvious. The large volume of nearly pure air at the top of the building is utilized, and a continuous inward current is insured towards those rooms which might otherwise be centers for the distribution of foul odors throughout the building. Similarly all the toilet rooms, instead of having their own air-supply flues, as is the case in eight of the large toilet rooms in the Court House, take their supply from the corridors through gratings in the lower panels of the doors, and the vent-flues from these rooms are all connected to an exhaust fan which is kept running continuously. Exhaust fans are also provided for the kitchen and restaurant, and for the laboratories, and these are run intermittently as needed. Ventilation in the stack rooms is required principally for the preservation of the books, so that the air from the library, which is usually a very thinly populated room, is entirely pure enough for the purpose, and it would, in fact, be wasteful to use fresh air.

There is a fourth exhaust fan in the State police department in the sub-basement, where confiscated liquors are disposed of. This was not anticipated in the original design, but was found necessary on account of the strong fumes liberated.

All the fans are run by electric motors. Vent-flues, other than

those mentioned above as being connected with fans, are merely carried up above the roof and suitably capped. No aspirating coils are provided or needed.

The total amount of air which the apparatus is capable of supplying to that portion of the building known as the "Extension" is 10,000,000 cubic feet per hour, or say 50 cubic feet per minute to each of 3,300 occupants. Add to this 2,500,000 cubic feet per hour for the Bulfinch and Bryant portions, and we get 12,500,000 cubic feet as the total for the completed building. This amount, it should be noted, is practically independent of outside weather conditions, and is well under the control of the engineer, who can reduce it as may be required. It is, of course, dependent on the fans and motors; if these should become disabled, then the air supply would be very greatly reduced, and with unfavorable weather conditions this building would be worse off than the Court House. But such a contingency is not likely to occur except at long intervals, and even then the stoppage would be of short duration and would not interfere with the use of the building.

We now come to the consideration of some of the details in the two buildings.

In the Court House there are twelve horizontal tubular hot-water boilers of 80 nominal horse-power each, and two steam boilers of the same type of 50 horse-power each, making a total of 1,060 nominal horse-power. The steam boilers are for the elevator pumps and have no connection with the heating apparatus except that the exhaust steam, after passing through a feed-water heater, escapes to aspirating coils in two of the vent-shafts. There is no electric lighting plant in the building. Of the twelve hot-water boilers, eight have been found sufficient in the coldest weather experienced since the apparatus was installed. The firing is done by hand, Cumberland coal being used.

In the State House there are four Babcock & Wilcox boilers of 208 nominal horse-power each, or 832 horse-power in all. These boilers are designed to supply steam to the entire heating apparatus, to the elevator pumps, and to a 5,000 lamp electric lighting plant. Last winter, beginning with January, the entire building—except that portion marked *M*, which was not built—was warmed by steam from these boilers, as was also a large building across the street on the east side known as the Commonwealth building. The electric current was at the same time supplied to 3,500 16-candle-power lamps or their equivalent, and in the coldest weather only three out of the four boilers were used, showing that there is an abundant reserve force to take care of the whole building when completed. Roney mechanical stokers are used for firing. The coal is brought from the bin in a steel car running on a 2-foot track, is weighed and shoveled into hoppers secured to the boiler fronts above the grates.

Special arrangement has been made for the disposal of ashes. Between and below the two pairs of boilers there is a fire-proof chamber with connection to each of the four ash pits; the ashes are dumped into this chamber and do not appear on the floor of the boiler room at all. A mechanical conveyer raises the ashes out of the chamber and deposits them through a chute outside the boiler-room wall, ready to be carted away.

In a hot water apparatus we should naturally expect to find the supply and return pipes of a larger size than those in a corresponding steam apparatus, so here, in the Court House, the main supply pipe or drum is 30-inch internal diameter, with 14-inch connections to twelve boilers. In the State House the largest supply main is 10 inches, with 8-inch connections to four boilers. The return mains in the Court House are the same size as the corresponding supply pipes, the return drum being 30 inches in diameter, whereas the largest return main in the State House is only 3½ inches in diameter.

All pipes in the Court House larger than 5 inches in diameter are of cast iron, flanged. No cast-iron pipes are used in the State House.

In the Court House the supply and return mains are in the sub-basement; the larger pipes run in the fresh-air supply ducts and are covered with hair felt and canvas, an excellent non-conductor for hot-water work, but objectionable from the fact that it has become infested with vermin. Each line of radiators has its separate supply and return riser, so that there are in the building 80 pairs of risers, not counting those which do not reach up to the second floor—160 rising lines in all.

In the State House the supply to the direct radiators is first taken to the top of the building by two 7-inch risers, and is thence distributed to the downward feed pipes by mains running in the roof space and covered with asbestos cement felting. Exclusive of those in the Bulfinch portion, there are 67 of these "droppers" or downward feeders which perform the function of carrying away the water of condensation as well as supplying steam to the radiators, so that no return risers are needed. The average size of these vertical pipes is very nearly the same in both buildings, about 2 inches in diameter. The "droppers" are concealed in slots in the brick walls, which are covered with cast-iron plates. These plates have perforations near the floor and near the ceiling, so that a circulation of air is maintained and the heat utilized. The ordinary pressure carried on the direct radiator system is under 5 pounds per square inch.

The direct radiators used in the Court House are constructed of one-inch pipe screwed into cast-iron headers at one end and into return bends at the other, the bends being tapped left hand. They are practically ordinary pipe radiators set with the pipes horizontal instead of

vertical. This form was adopted partly because of the ease with which such radiators can be made of varying heights, widths and lengths to suit the different window recesses and the amount of surface specified.

The State House radiators are of the H. B. Smith Union pattern for hot water, vertical cast-iron loops connected together at top and bottom. Each radiator has a supply connection at the top and return connection at the bottom, both connecting with the same vertical pipe.

The amount of radiating surface in the Court House is vastly larger than in the State House, notwithstanding that the latter is the larger building and has ample surface to more than meet all the requirements. I am not able to state exactly the area of the exposed window and wall surface in the two buildings, but it is probable that the proportion of such surface to cubic capacity is greater in the Court House than in the State House, and the actual figures might possibly show a surplus for the Court House. Bearing this in mind, and also making liberal allowance for the fact that we are dealing with hot water in one case and with steam in the other, it is still very evident that an extravagant factor of safety was used in designing the Court House apparatus.

For purposes of comparison I have selected a large room in each building, which will, I think, help to bring out this point more clearly. The room in the County building which I have chosen is one of the Court rooms on the second floor on the west side (Fig. 6), and the one in the State Building is on the third floor on the east side, and was originally assigned to the Secretary of State (Fig. 5). Their respective locations are indicated by the letters *E*, *E* on the floor plans. They were chosen with reference to their size and exposure, and by referring to Table II it will be seen that while the rooms vary very little in those particulars, yet the Court Room has 89 per cent. more direct surface and 1,347 per cent. more indirect surface than has the room in the State House. It should be noted, however, that this difference is in part due to the use of hot water without a fan in one case, and steam with a fan in the other, and also to the fact that on account of the larger number of occupants in the Court Room, a larger maximum air supply has been provided for. But even when all this has been taken into consideration, the excess in the Court Room is still very remarkable, and I do not think that "extravagant" is too strong a term to apply to the "factor of safety" there used.

The figure 85 which is given in Table II as the amount of indirect surface for the room in the State House is in the same proportion to the total indirect heating surface on the east side (4,240 square feet), as the amount of air supplied per hour to the room (150,000 cubic feet) is to the total air supply per hour (4,500,000).

TABLE II.

	Court House. Room 22, 2d Floor.	State House. Room 113, 3d Floor.
Floor area, square feet	1,813	2,090
Cubic capacity	38,300	39,700
Glass area	340	260
Exposed wall area	920	994
Glass plus wall	1,260	1,254
H. S. direct	512	270
H. S. indirect	1,230	85

By referring to Table I, it will be seen that much the same proportions are maintained when the two entire buildings are compared. The Court House, with 11 per cent. less cubic capacity, has 318 per cent. more heating surface, and this is without taking into account the large amount of surface in the enormous supply and return mains.

With regard to the coal consumption in the two buildings, I have not found it possible to get data for a fair comparison. The amount used in the Court House from January 1 to June 1, 1895, was 995 tons, and in the State House for the same period, 1,465 tons. But it must be remembered that in the latter building there is a 5000-lamp electric light plant, some portion of which was in operation day and night, and that the Commonwealth Building, the Bulfinch and Bryant portions, and the Extension (except that part over Mt. Vernon Street), were all warmed during this period by steam from the new boilers. Also it should be noted that the north side of the Bryant portion and the south end of the Extension were then outside exposures.

The electric lighting bill for the Court House, covering the period above mentioned, was $3,030, which must be placed against the State House expenses. This is enough to pay for the extra coal used in that building and leave a balance of $300 a month towards the heavier running expenses, but even then we do not get an accurate comparison, as many more lamps are used per hour in the State House, and there are six elevators there against three in the Court House.

The number of employees in the engineer's department is greater in the State House than in the Court House, partly because of the lighting plant, and partly because of the State law which limits the working hours of State employees to eight in twenty-four, a law which does not affect the Court House. There are in the State House three engineers, six firemen, three oilers and two electricians, against two engineers, five firemen and one electrician in the Court House.

The Court House apparatus was designed by Bartlett, Hayward & Co., of Baltimore, and installed by the Samuel I. Pope Co., of Chicago. That in the State House was designed by Prof. S. H. Woodbridge, of the Massachusetts Institution of Technology, and installed by A. B. Franklin, of Boston.

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RECONSTRUCTION OF THE CAR FERRY TRANSFER APRONS AT PORT COSTA AND BENICIA.

BY JOHN B. LEONARD, MEMBER OF THE TECHNICAL SOCIETY OF THE PACIFIC COAST.

[Read before the Society, May 3, 1895.*]

FOR the data upon which I have based my description of the operating machinery, I am indebted to the paper prepared by Mr. A. Brown and read by Mr. Harris before the American Society of Civil Engineers in April, 1890. I also wish to acknowledge many favors tendered to me by Mr. F. Teichman, who, under the supervision of the Engineer of the Maintenance of Way Department of the S. P. R. R., prepared the details for this work.

The steamer "Solano" was built in 1879 for the purpose of transferring a train of cars (48 freight or 24 passenger, with engine) across the straits of Carquinez between Port Costa and Benicia.

The transfer aprons that I will attempt to describe to you are for the purpose of connecting the tracks on the wharves with those on the boat.

The "Solano" having been in service for a period of sixteen years, it became advisable to dock her and make some needed repairs. This opportunity was taken to reconstruct the transfer aprons. It had for some time been apparent to the engineers of the Maintenance of Way

* Manuscript received October 18, 1895.—*Secretary, Ass'n of Eng. Socs.*

Department of the Railroad, that the construction of these transfer aprons was much too light for the present traffic. The increased volume of business and the much heavier rolling stock that is now being used are the reasons for strengthening these aprons.

Fig. 1 shows the general details of the aprons as originally constructed. The apron, as reconstructed, will have practically the same general dimensions as those of the original apron, *i. e.*, 100 feet long by 44½ feet wide, and will carry four tracks similar to those on the boat. The apron will consist of five longitudinal bowstring trusses, and a system of transverse floor beams carrying intermediate track stringers.

One end of the apron is at all times supported by the wharf, and is also hinged at this end. The other end is supported by means of a submerged pontoon and counterweights, but during the operation of loading or unloading, additional support is given by the boat.

The supporting capacity of the pontoon is 95 tons, and of the counterweights 25 tons, making a total supporting capacity of 120 tons. An excess of supporting capacity to the proportion of static load that is carried at the free end, is for the manipulation of this end of the apron. The machinery for doing this will remain the same as in the original construction.

At the first panel point from the free end, the apron will rest on the pontoon. At a distance of 12′ 1¾″ from the free end there will be a transverse bowstring truss, the ends of which will be secured to the counterweights. This transverse bowstring truss will transmit to the longitudinal apron trusses the supporting power of the counterweights. The wire rope which connects the ends of the transverse truss to the counterweight is double and continuous, and passes around equalizing sheaves both at the truss and the counterweight. The pontoon is connected to the apron in such a way as to resist both tensile and compressive stresses.

The power for operating the counterweights is derived from a hydraulic lift. From the top of the box containing the counterpoises, the chain K passes partially around the sheaves l and m, the crosshead T, and is secured at n. From the bottom of the counterweight the chain K' passes similarly around l' and m', and is secured at n'. The water is supplied from the accumulator G, into which it is pumped from the tank R, on the Benicia side, by an electric motor. On the Port Costa side the tank R is situated on top of a hill and is supplied by the local water works. The distribution valve of the lift T, shown in detail on Fig. 1, is so arranged that when the feed is cut off, the ends of the cylinder are connected, so that the piston may move in either direction, the water in the cylinder merely circulating around, thus permitting the end of the apron to rise and fall with the tide or the boat.

The action of the free end of the apron is as follows: the excess of the supporting capacities raises the apron above its bearing in the cockpit of the boat, when such bearings are at the maximum elevation, *i. e.*, the boat is unloaded. The boat comes into the slip to receive or discharge a train. A horizontal motion of the hydraulic lift in the direction of the wharf raises the counterweight, and thus throws an unbalanced weight on the pontoon. This unbalanced weight sinks the pontoon until the trusses of the apron come to their bearing in the cockpit of the boat. The apron is then latched down and the counterweights released. The boat is held up to the apron by means of two mooring rods *M*, which extend the length of the apron, are hinged at *H* and bolted back to the piling as shown. The rods *M* are connected to the boat by means of links and tightening levers. The apron is now free to follow the fluctuations of the boat due to loading and unloading, or the rise and fall of the tide. Upon unlatching the apron the unbalanced weight immediately raises the apron free from its bearings. The object of connecting the crosshead *T* to the bottom of the counterweight is to keep the piston always in a position ready to act at once.

The two outer trusses of the apron will carry the outer rails of the outside tracks on their top chords, while the other rails will be carried by 14 x 16 track stringers which rest on the transverse floor beams.

The trusses are of the pin-connected combination type of construction. Each truss has six panels of 13′ 3″ each, and one 18′ 3″, making 99′ 3″ center to center of end pins, and a depth at their center of 8′ 6½″ center to center of pins. The depth of the trusses was limited by the distance from the base of the rail on the boat to the loaded water line. The form of the trusses is such as to secure very nearly the same maximum stress in each panel under the conditions of maximum loading for such panel.

The trusses are built in duplicate for the sake of economy in the cost of manufacturing and erection. The only places where there is any excess of material are the web systems and bottom chords of the outside trusses. The transverse stresses of the top chords in these trusses, in addition to the logitudinal stress, require about the same sectional areas as are used in the other trusses.

The maximum unit strain in the tension members will be 15,000 pounds per square inch, and this strain will occur only when trains are on adjacent tracks.

The top chords of the trusses are built of three pieces of Oregon pine, 8″ x 16″, and two 15″ steel I-beams, 41 pounds per foot. The 15″ beams are placed one on each side of the timber chords, the timber being framed so as to fit snugly up against the web of the beam. The web members are connected to this chord by means of pins, these pins having bearings

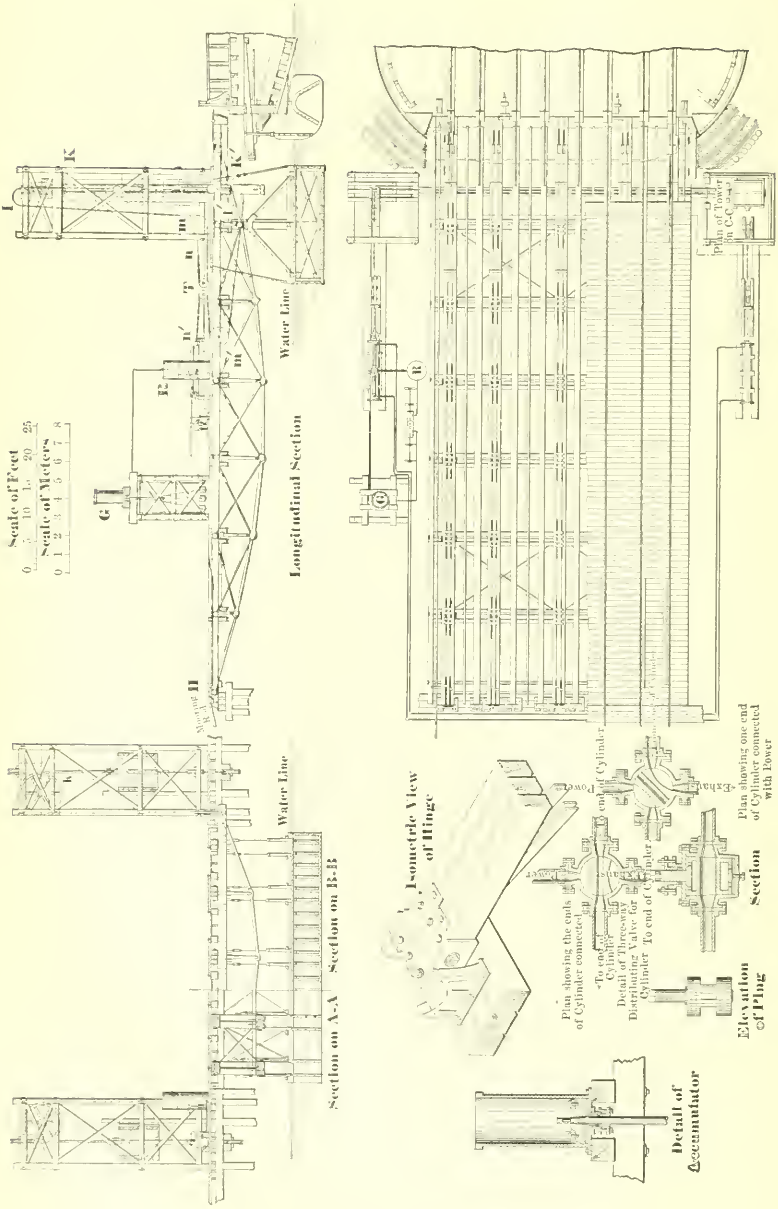
Scale of Feet
Scale of Meters
Longitudinal Section
Water Line
Section on A-A
Section on B-B
Plan of Tower on C-C
Isometric View of Hinge
Plan showing the ends of Cylinder connected
Detail of Three-way Distributing Valve for Cylinder
Plan showing one end of Cylinder connected with Power
Section
Elevation of Plug
Detail of Accumulator

FIG. 1.

in castings. The castings rest on top of, and are bolted to, the vertical posts, and project up between the leaves of the timber portion of the chord, into which they are framed. The diameter of the pin hole in the timber is such as to make a snug fit, while those of the beams are $\frac{7}{8}''$ larger than the pin. In this way all of the horizontal components of the diagonal web members are transmitted to the timber portion of the chord. At the ends of the trusses the beams are riveted to the castings, and both beams and timbers come to a bearing on the pin. To insure the timber coming to a firm bearing in the castings, iron wedges will be driven in the joints at the ends of the timbers.

The reasons for building the chords in this way are these: First, it was found to be much cheaper than an all iron construction, one item in favor of the cost of this construction being that the most of the cast iron is taken from the old work. The limited time in which to perform the work was a very important factor against an iron truss or girder. An all timber chord could not be used because it packed out too wide horizontally with a 16″ depth, and to increase the depth of the timber sufficiently to permit it to be packed in the horizontal space available, would decrease the depth of the truss, or in extreme cases dip the bottom chord too much into the water.

For proportioning the chord sections the moduli of elasticity of timber is taken at 1,800,000 pounds, and of steel, at 29,000,000 pounds. Since the two materials will resist the stresses in proportion to their rigidities, which from the above moduli are found to be nearly as 16 to 1, the sectional area of the timber to the steel is as 16 to 1, as near as commercial sizes will permit.

Furthermore, it is found practically impossible to bring the apron to an exact bearing in the cockpit of the boat, there being a play of about $\frac{1}{2}''$ between the sill of the apron and its bearing on the boat, under favorable conditions. The sudden loading of the apron caused by the train coming on from the boat, immediately deflects the end of the apron to its bearing. To overcome the inertia of the counterweights and the pontoon, a transverse bending strain is produced in the end panels of the top chords.

A variation in the elevation of the sides of the boat during the operation of loading or unloading, produces a torsional action in the apron. Experience has shown that the action of the bending stresses and the stresses caused by the torsional motion of the apron are very destructive to a timber chord. It is believed that the addition of steel beams to the chord section will prove advantageous in resisting such stresses.

The variation in temperature has been assumed as 40° between extremes. With the work placed in position at a mean temperature,

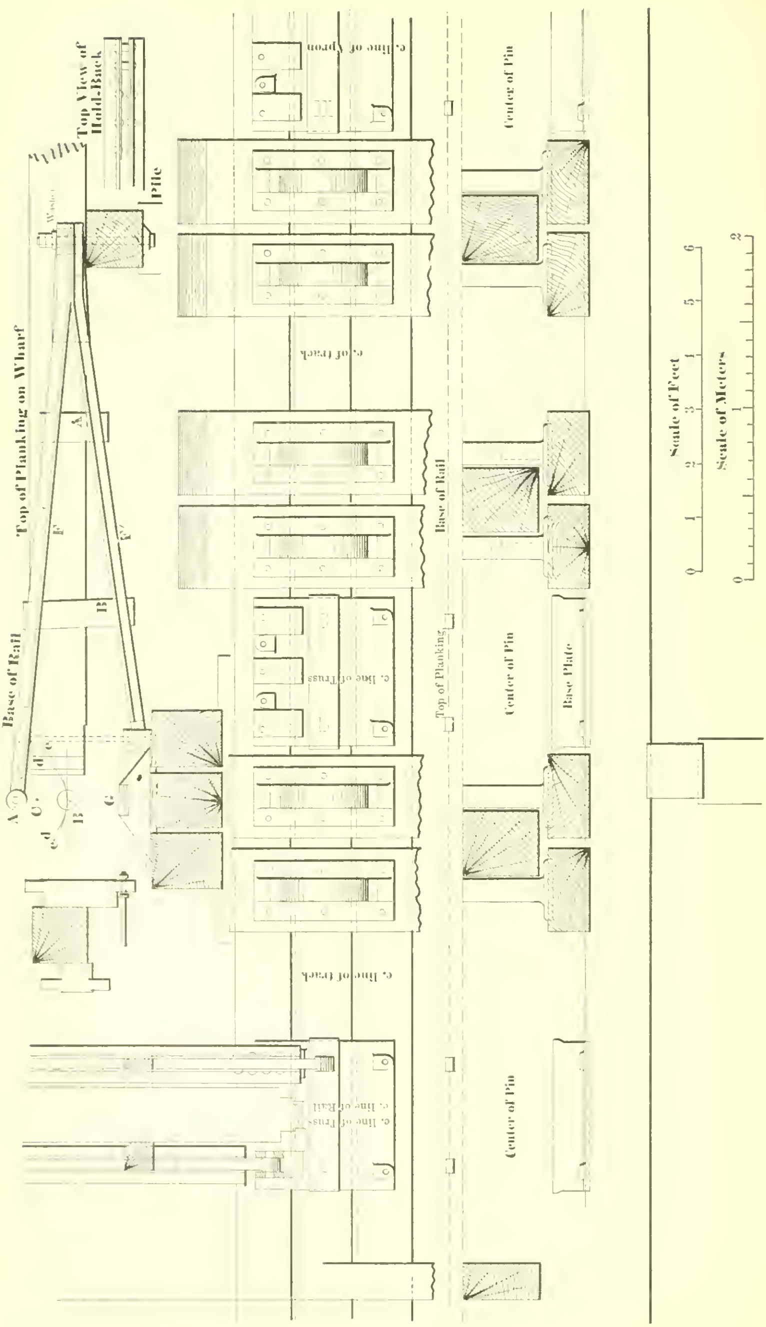
Top View of Hold-Back
Pile
Washer
Top of Planking on Wharf
Base of Rail
c. line of Apron
c. of track
Center of Pin
Base of Rail
Top of Planking
c. line of Truss
Base Plate
c. line of track
c. line of Rail
c. line of Truss
Scale of Feet
Scale of Meters

FIG. 2.

the 40° variation will cause a difference in length of the timber and iron sections of about $\frac{1}{20}''$. The deflection of the pin will be sufficient to overcome this variation.

The stringers at the wharf end will fit into a casting which will have projections on its sides. The projections will be in the form of a segment of a curve, and will extend out from the face of the casting. This projection will rest in a socket of a similar concave curvature, in a pedestal casting which rests on the wharf. In this way an axis of rotation for the stringers is provided.

For the trusses the problem is very different. An inclination of the apron above or below the horizontal line passing through the hinge creates a thrust or pull at the hinge which must be resisted.

A large radius for the rolling face was necessary in order to secure sufficient bearing power. It was also sought to secure a detail which would cause the apron to automatically adjust itself to its normal position when horizontal. These conditions are believed to have been fulfilled in the detail adopted. The end pin B (Fig. 3) of the truss rests upon the rocker R, and transmits through it to the wharf the portion of the load that is brought to this end of the truss. The pin A (Fig. 2) is the hinge pin, about which the apron revolves.

The point C is the center of the curve of the bearing face of the rocker, the radius being 18″. The end pin B of the truss is 7″ below this center of curvature.

The hinge pin A is 11″ above the end pin B, and 22″ above the bearing point G. The pin A is held in a position that is at all times vertically over G, G being the center of pressure when the rocker is vertical. This is done by extending braces F, F' backwards from A and G and securing them to the wharf. The struts are joined to one another at the wharf end, and also at points intermediate between the wharf connection and the points A and G, thus completing the triangle of bracing. There are a pair of these braces to each truss. The apron is connected to the hinge by giving the pin A a bearing in the end casting. The horizontal motion of the pin B, due to the extreme position of the apron, was found to be about $\frac{1}{2}''$ each side of the vertical.

The path of motion of the pin B is along the curve B, e. If the hinge were held rigidly in position, its path of motion would have to be along B, d, consequently the hinge A will have to be deflected a distance equal to the space between the two curves B, e, and B, d. This distance was found to never exceed about $\frac{1}{32}''$, a deflection which will be given by the elasticity of the strut with ease.

The point B being below the center of curvature of the rolling face, the tendency of the apron must always be to return to its normal

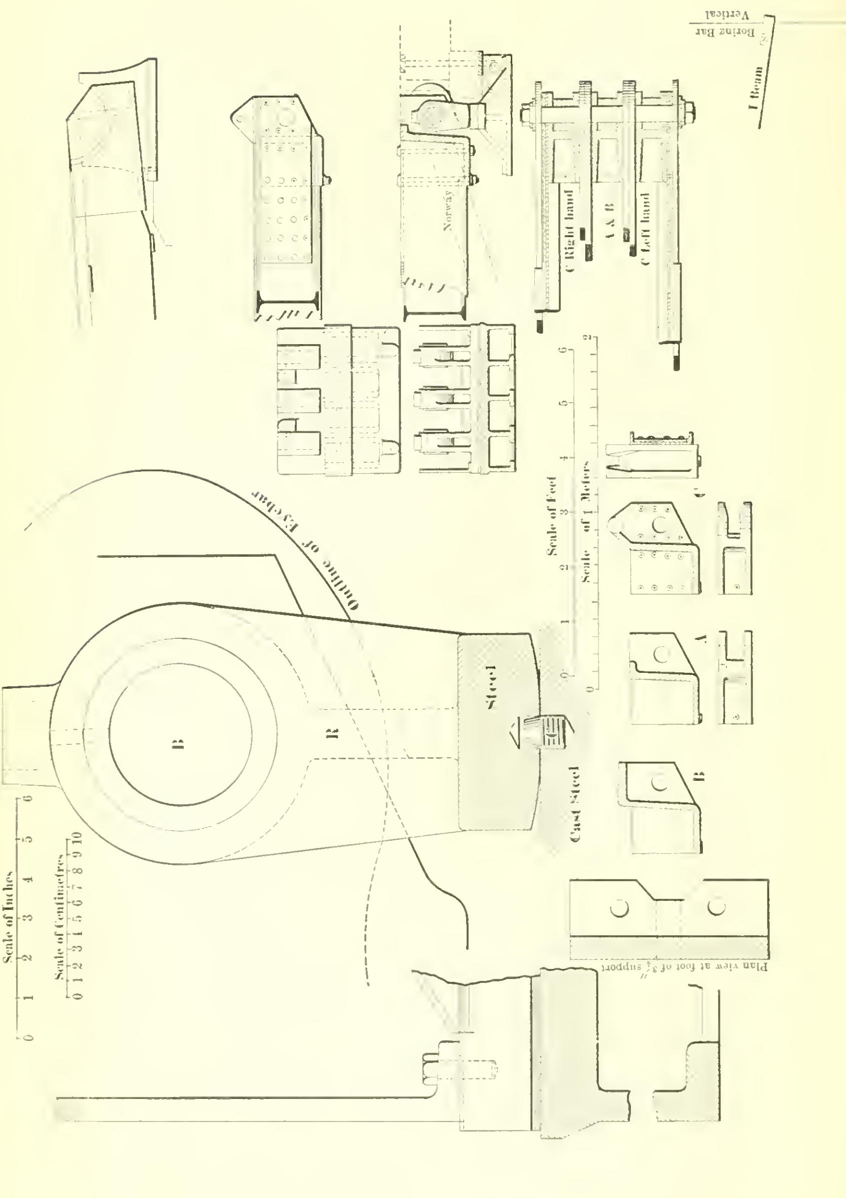
Scale of Inches
Scale of Centimetres
Outline of Eyebar
Steel
Cast Steel
Norway
C Right hand
A & B
C Left hand
Scale of Feet
I Beam
Boring Bar
Vertical

FIG. 3.

position. The stress produced in the strut F when the point B is at its maximum distance from the vertical line, is about 1,400 pounds. To prevent the rocker being lifted off its bearing through any blow or shock, the tap bolt C is placed in the pedestal.

The eyebars for this work were made by the Pacific Rolling Mill Co., of San Francisco. The balance of the shop work was done by the railroad shops at Sacramento.

PAMPHLET FILING.

By William H. Bryan, Member of the Engineers' Club of St. Louis.

[Read before the Club, October 16, 1895.*]

Every engineer comes into the possession of numerous folders, pamphlets, circulars and catalogues which seem worth preserving. If he is a member of one or more of the national societies, the number is increased. If, in addition, he is represented by cards in the professional directories, the amount of this literature becomes larger still.

These pamphlets are of every imaginable size and shape, and cover all branches of engineering, and are often on subjects of only indirect interest to the engineer. Unfortunately they differ widely in shape and size, from a single card or leaflet, to a bound catalogue of many hundred pages. The list comprises manufacturers' catalogues, stock and price lists, advertisements, specifications, reports, ordinances, results of tests, clippings, and miscellaneous pamphlets of a fragmentary character of every imaginable description. Much that the average engineer receives is, of course, not worth preserving, but, on the other hand, a considerable portion of it, if not of actual value at the moment, is well worth preserving with a view of its future possible use. Some of it is of great value, as it represents the latest practice in certain lines, which is not as yet old enough to be incorporated in the text-books, or engineer's pocket books, much of it not having even reached the engineering press. Many manufacturers add a value to their catalogues by incorporating in them numerous tables and formulæ. As a rule these are carefully collected and represent good practice. Not infrequently they contain data not accessible elsewhere. Some of these are so valuable that the engineer consults them frequently and keeps them close at hand. A good example of this is "Helios, a Text Book of Modern Boiler Practice," recently issued by the Heine Safety Boiler Company of this city. Others, however, are of quite a different character and some judgment must be used in determining their merits. Within the last week I received a circular in which the time-honored rule that the evaporation of a cubic foot of water per hour represented one boiler horse-power, was stated in all seriousness.

There can be no argument as to the desirability of preserving this matter, but unless a well-digested system of filing and indexing is employed, the accumulation soon reaches a point where it become unwieldy, and the difficulty—if not impossibility—of finding any desired pamphlet,

* Manuscript received November 11, 1895.—*Secretary, Ass'n of Eng. Socs.*

prevents any considerable use being made of them, and greatly reduces —if it does not wholly destroy—their value. Very early in my own experience I found that I must adopt a system which would make it possible to put my hands immediately upon all the accumulated matter upon any one of many different subjects. As other engineers have no doubt been confronted with the same difficulties, I have thought it might be of interest to explain the solution which I finally reached.

Any satisfactory plan must of necessity be simple in design and arrangement, complete, occupy little space, and not be expensive in first cost. It should be possible to remove and replace any single pamphlet without disturbing the others. Above all, the system must be so nearly "automatic" as to require the minimum of thought and labor to maintain it at its highest efficiency.

The large bound catalogues are, of course, easily handled. Most of

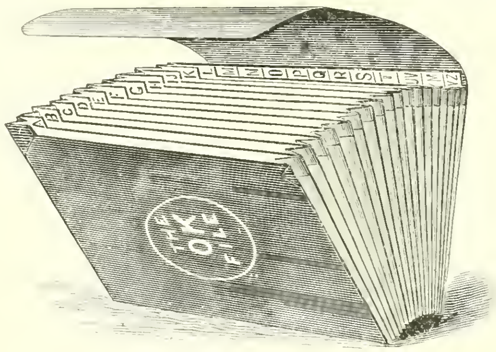

Fig. 1.

them are worthy of a place on the shelves of our book cases. The smaller and irregularly shaped pamphlets are the ones which present difficulties. In my early days a few heavy envelopes in three or four leading divisions of engineering answered the purpose. These were simply labeled as to their general character, and each individual pamphlet or clipping was also indexed. This was further increased by additional envelopes of the same character, as the accumulation grew. For obvious reasons, however, this plan soon failed, the envelopes being quite limited in capacity, and the system having little or no elasticity. The next step was the use of the flexible paper letter files, Fig. 1. These cost from 25 cents to 35 cents each, and contain twenty-two divisions. A label is placed on each division giving the title or subject to which it is devoted. These permit quite a variety of subjects and each division may be somewhat overcrowded. This system lasted me until within the last year, adding cases from time to time, and rearranging the subjects. I found in practice, however, that many of the divisions became badly

overcrowded, and that the cases would not stand the hard service due to frequent reference to their contents. Furthermore, the divisions are not readily accessible where the filing cases are all kept together on shelves, it being necessary to remove the entire case to get at any particular division. Dust also gets into the divisions.

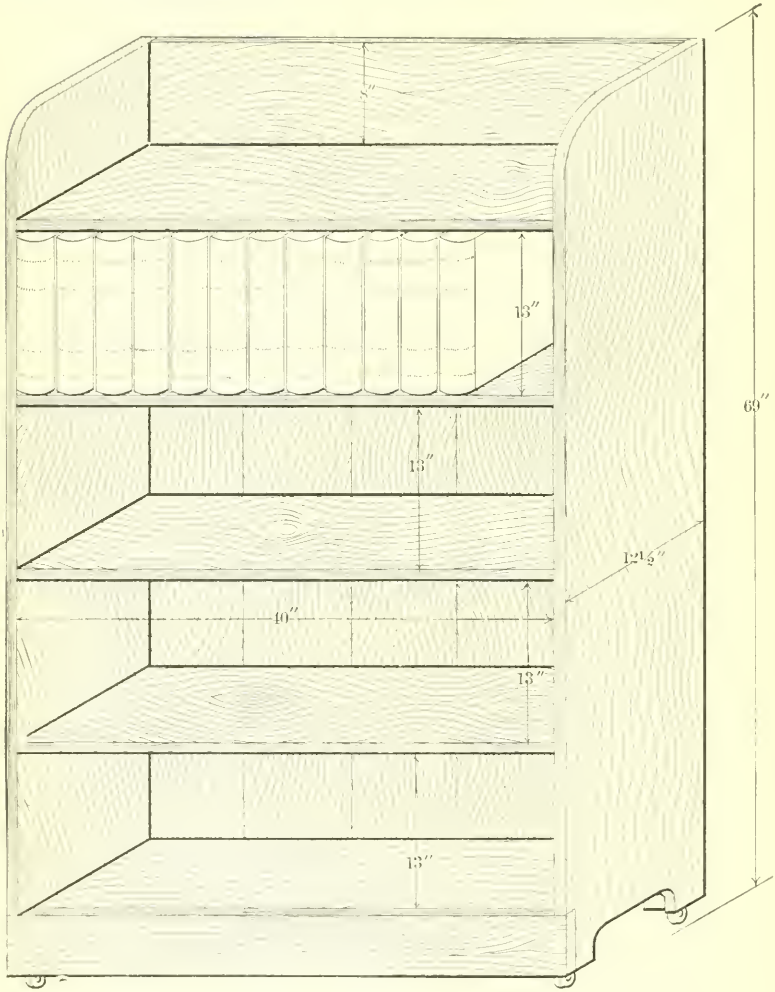

Fig. 2

Less than a year ago, I realized that it was necessary to radically change my system if I desired to be able to get the full benefit of the matter in my possession. I devoted a great deal of study to the matter, investigating all sorts of filing systems, shelves, cases of drawers, etc., but

found nothing which was at all suitable. The standard sizes were either not satisfactory as to size, or shape, or they occupied too much room, or were too expensive. The latter was true also of any special design which might be gotten up.

The accompanying sketch, Fig. 2, indicates my solution of the difficulty. I had a case of shelves made, of shape and dimensions shown. There are five shelves, each 40 inches wide and 13 inches high in the clear. The ends, tops, and facings of the shelves, are of antique oak; the rest of the case being of ordinary material, poplar, I believe. The case is on rollers.

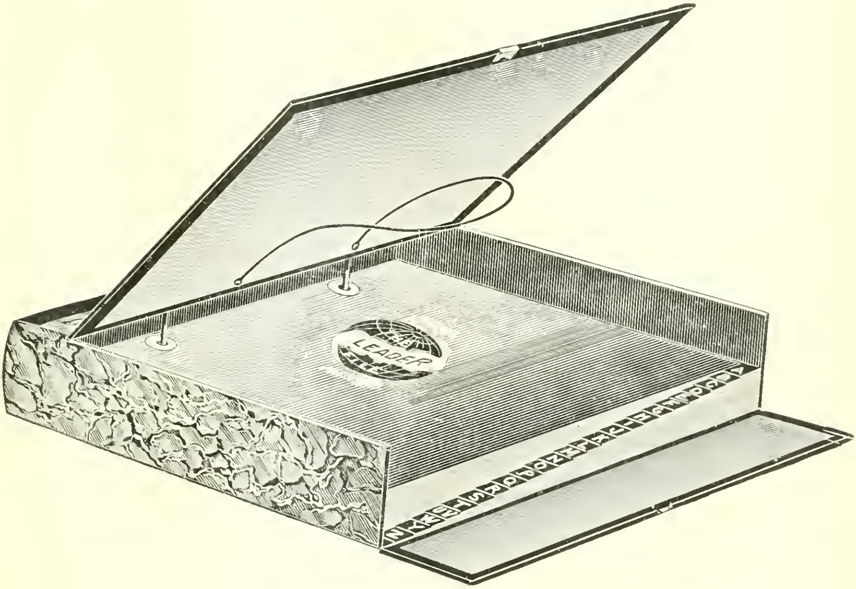

Fig. 3.

I then ordered five dozen "Perfection" letter file cases of standard size, which is 12 x $10\frac{1}{2}$ x $2\frac{3}{4}$ deep, Fig. 3. I had partitions placed in forty of them, giving me eighty divisions of about $1\frac{3}{8}$ inches depth, for ordinary use, the remaining twenty being full depth and intended for those subjects on which an unusual amount of matter had or might be accumulated. The cases are sufficiently large to receive any of the standard sizes of catalogues or pamphlets. In fact, there are but few odds and ends of eccentric shape that cannot be handled. The case of shelves cost $7.00 and the letter files $16.50, being $2.50 per dozen, with an extra charge of ten cents per case for the partitions; a total of $23.50.

Each of the five shelves contains twelve filing cases, with 3 or 4

inches of space to spare to permit easy handling, as well as some over-crowding of cases, or even an additional case on each shelf.

Each of the one hundred divisions is numbered, and bears also a label indicating its contents. In my desk I keep an index, which is a copy of the labels on the individual cases. When the literature is received, it is first examined to determine whether it appears worthy of preservation. If worth saving, it is placed temporarily in a convenient drawer in my desk. When this drawer becomes filled—which in my own case often happens two or three times a month—all the accumulated matter is gone over again and examined more carefully. On each pamphlet which I decide to preserve, I mark the number of the filing division into which it is to go. The whole is then turned over to an assistant, who files the pamphlets in their proper places.

When I desire to look up any particular subject, I turn to my index, ascertain the number of the division, and request an assistant to bring me the proper case. As my system of indexing is alphabetical, however, it is frequently quite as convenient to go directly to the shelves and pick out the case desired. If a single pamphlet is being consulted, it can, when I am through with it, be placed temporarily in the receiving drawer, if there is not time enough to file it away permanently.

In practice, I have found that still further division is necessary on some subjects. To carry these out I use large Manilla envelopes, each bearing a sub-heading corresponding to the branch of the subject it serves.

To carry out the system in its best shape it is necessary to go through the cases carefully every year or two, making provision for new subjects which have arisen, relieving over-loaded divisions, and weeding out duplicates and matter which has become antiquated, or is of doubtful value

The system represents an investment of but $23 50, but its value to me is many times that amount. If I include its contents, I can hardly place a value on it, as much of the matter could not be replaced. I can assure you that the ability to put my hands at once upon all the matter of this character which I have accumulated for years, on over one hundred subjects, is a profound satisfaction, and I feel that I have mastered the pamphlet-filing problem for some years to come at least.

A less elaborate system would answer for many engineers, and even the small investment required may not always be convenient to make. In such cases the filing by divisions in the ordinary flexible letter file, Fig. 1, will be found quite inexpensive and satisfactory.

STREAM MEASUREMENTS AND WATER POWER IN VIRGINIA AND WEST VIRGINIA.

By D. C. Humphreys, Member of the Association of Engineers of Virginia.

[Read before the Association, November 23, 1895.*]

Those of this Association who were present at the summer meeting in Lexington will remember that Mr. F. H. Newell, Hydrographer of the United States Geological Survey, was present, and gave us a talk on the work and methods of the Survey.

At that time, no work in stream measurement had been done in the Virginias, except along the Potomac River; since that time, at the request of the Survey, I have undertaken to do what I could in investigating the water resources of the States of Virginia and West Virginia as far as the limited amount of money that could be placed at my disposal for that purpose would permit.

I am satisfied that the work which has been begun will be of great value to the two States, if it can be continued and enlarged. Knowing the interest our Association takes in all such investigations, I offer this paper as a sort of progress report.

The origin of this investigation will be found in Major J. W. Powell's "Report on the Lands of the Arid Region of the United States," 1878, which was the result of surveys made under him. In March, 1888, the Director of the Geological Survey was directed to make examinations relating to water storage, the volume of streams, and similar questions.

October 2, 1888, the "Irrigation Survey" was created, and March 2, 1889, it was extended, but the appropriations for it were abruptly cut off in 1890, after which date stream measurements were carried on only incidentally along with the topographical surveys.

On March 18, 1894, an appropriation of $12,500 was made to investigate the water resources of the United States, and by Act of March 3, 1895, $20,000 were appropriated, which is the amount available to June 30, 1896.

In regard to the work Mr. Newell says: "In the attempt to carry on work in all parts of the United States, as well as to pay all incidental office expenses, it results that the amount for any one locality is very small, especially in the East; since the arid regions demand the larger share of attention."

* Manuscript received December 5, 1895.—*Secretary, Ass'n of Eng. Socs.*

The reasons for the larger share going to the arid lands is not hard to find.

I. The General Government owns about one-third of our territory by absolute right, and the investigation is calculated to greatly enhance the value of the Government's own property.

II. The value of water, on account of the very limited supply, is much greater in the West than in the East; and, to use the rivers to the best advantage, in the arid region, it is necessary that a comprehensive plan should be adopted, which the separate States cannot do, as the rivers go from one State to another, and so pass from one control and jurisdiction to another.

III. The question of artesian wells and storage can only be answered after a comprehensive and extended survey, and geological investigation, such as the U. S. Geological Survey is now making.

IV. On account of the vital importance to them, Western representatives in Congress have been zealous in getting appropriations passed for the purpose, with the tacit understanding that the money should largely be spent in their section; in which there would seem to be some justice since they have no harbors nor navigable rivers to improve.

The complete success of the gigantic scheme for utilizing some of the power of Niagara, together with many even greater successes, on a smaller scale, in transmitting water power electrically, has turned the attention of our profession, and fired the imagination of the general public, to the splendid possibilities of using the vast wealth of power which is now going to waste in our water courses in the Appalachian Mountains.

The best water powers have a way of being in places very difficult of access, but the perfecting of the alternating motor under Nicola Tesla and others has made all water power available, as it can be easily transmitted to towns and railway stations. The cost of electrical apparatus is such that it cannot be said the transmission can be cheaply done, especially when the current has to be transformed up, then down again, which is necessary if the distance be long; so that in many cases the railway coal car will remain the cheapest transmitter of energy.

The newly acquired importance of all water powers has attracted the attention of our public men, and as a result the investigation of the water resources of the United States now includes the East as well as the West, and especially the mountainous portions of the East.

To properly carry on the investigation the Survey should have enough money, so that at least $20,000 could be annually spent on the Appalachian region alone. It is to be hoped, Congress will see its way clear to provide for this work, and the justice might be put on the same ground as it is in the far West, that we have neither harbors nor navigable waters in the mountain country.

The value of this investigation of water power need hardly be pointed out to this Association; still it will be proper to state not only what has been done, but also what is proposed, and what sort of information we hope to be able to give those contemplating the use of water power.

In the Virginias, stations have been established and measurements are being made: *On the Potomac* at Dam No. 6, near Great Cacapon, W.Va.; on the South Branch, at Springfield, W. Va.; on the main river at Cumberland, Md.; on the Shenandoah near Millville, W. Va.; on the Potomac at the Point of Rocks, Md., and at Chain Bridge, D. C. At these stations the work has been largely done by Mr. C. C. Babb, Assistant Hydrographer of the Survey,* who also assisted me in selecting and establishing most of the following stations which I am now looking after. *On New River*, at Lafayette, W. Va.; on the *Greenbrier*, at Alderson, W. Va.; on the *James*, at Buchanan, Va.; on *North River*, of the James, at Glasgow, Va.; on *North and South Rivers*, of the Shenandoah, at Port Republic, Va.; six stations in all.

The observations at each station consist of two parts.

(1) The river height is daily read by a gauge reader, who lives close to the station, and a weekly report is made to me, which, after copying it, I send on to Washington.

(2) The relation must be established between river height and discharge per second; when this is once done all that is necessary in order to ascertain the quantity of water flowing by per second is to measure the river height, or read the gauge, then by a rating table or diagram determine the discharge.

To obtain trustworthy results it is necessary that the station be chosen at a place where the cross-section and channel above and below shall be permanent. This can be easily done in the mountains or rocky country, while on the Mississippi and Missouri Rivers, where I was formerly engaged, it was an impossibility.

To establish this relation between gauge reading and discharge, measurements must be made at different stages, from extreme high water to extreme low water; thus establishing points along the curve expressing such relation. It is obvious that for power purposes the low water discharge is the important one, and therefore more measurements are made at low water than at any other stage. High water discharge is important as effecting the elevation to be given the buildings above the crest of a newly erected dam, also as effecting storage.

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* The results of some of his work were given to the public in a paper, "The Hydrography of the Potomac Basin," by Cyrus C. Babb, *Transactions of the American Society of Civil Engineers*, XXVII, pp. 21–38, July, 1892.

In this work I am using one of two meters which are at my disposal.

(1) A Haskell electric meter, which is let down usually from a bridge attached to a compound electric cable which serves as a cord to hold up the meter, as an electric conductor for recording the revolutions of the wheel, and as a sounding line, being tagged with red and white for that purpose. A heavy weight attached to the bottom of the meter causes it to sink nearly vertically in the water while the tail keeps the wheel pointed towards the current. The electricity is furnished by a small (2″ x 1″) bisulphate of mercury wet battery, which is a model of compactness and convenience, and it always works whenever I have tried to use it, which I consider a big compliment to any field electric battery. I can't say so much for the electric part of the meter, for I nearly always have some trouble with it, owing usually to a little water getting into a place where it is not wanted. When, for any reason it don't work well, it is a matter of the utmost importance not to be in any hurry while fixing it.

(2) A meter made by Newton, of London, such as is supplied to the Admiralty, this one belonging to Washington and Lee University. The registering apparatus is put in gear by pulling a string, and released by slacking the pull; this makes it almost necessary to attach it to a rod, so that it cannot be used in measuring from a bridge. It is specially adapted to measuring by wading, and is well suited to work from a boat. It has the merit of being simple and cheap, so that it can hardly be recommended it too highly.

Wherever it can be done, a bridge is selected, because of the cheapness of gauging from it, and discharge measurement can be made by one man, if necessary, while no more assistance is needed than can be rendered by a boy. Next in order of desirability is a cable, on which a small car travels, large enough to hold one man, who lets down his electric meter from the car, while he gets his distances from the bank by a tagged wire suspended above the cable. This method has the disadvantage of being costly to construct, but has the advantage that you can locate it at a suitable place for accurate measurement.

In warm weather, and low water in the smaller streams, wading is the best method.

The method to be used when all others fail, is to work from a boat, which, if the stream be narrow, is pulled along a cable, while, if it be wide, the position of the boat will have to be located by some indirect method.

The following stream measurements have been made in the Virginias, not including the Potomac measurements:

River.	Locality.	Date.	Discharge, in cu. ft. per second.	Water Power per foot Fall.
New,	Fayette, W. Va.,	July 29, '95.	7128	810.0
"	" "	Sept. 4, "	3030	345.0
Greenbrier,	Alderson, "	July 30, "	457	52.0
"	" "	Sept. 4, "	106	12.0
James,	Buchanan, Va.,	July 3, "	509	57.9
"	" "	Aug. 1, "	543	61.8
"	" "	Sept. 6, "	397	45.1
North (of James),	Glasgow, "	Aug. 24, "	201	22.8
" "	Lexington, "	Aug. 2, "	135	15.2
" "	" "	Sept. 7, "	82	9.3
" "	" "	" 17, "	81	9.2
North (of Shenandoah),	Port Republic, Va.,	Aug. 6, "	374	42.5
" "	" " "	" 29, "	258	29 3
South, "	" " "	" 6, "	114	13.0
" "	" " "	" 29, "	87	9.9
" "	Basic City, "	" 5, "	72	8.2
North Fork, "	Riverton, "	" 7, "	362	41.0
South Fork, "	" "	" 7, "	791	90.0

The measurements made in the latter part of August and early in September, give the low water discharge, nearly, except in the case of New River, which was on October 4th, two feet lower than when it was measured September 4th.

The largest power that I have seen, and probably the finest in the two States, is in the New River Cañon, where the fall is over twenty feet to the mile, and the distance is about sixty-four miles. Taking my smallest measurement, that of September 4, 1895, the total horse-power going to waste in the cañon is 442,300, sufficient to move about 1,000 trains, to do which with coal would require over 1,000 tons of coal per hour.

This vast power is situated in the midst of one of the finest coal fields in the world, where power from steam is cheapest, so that its use may be postponed, but it will some day be developed, when our inexhaustible coal fields are in the same condition that our inexhaustible forests now are. But it may come sooner, when the C. & O. R. R. shall use it for driving its trains by electricity, and passengers on the F. F. V. can see Hawk's Nest without getting cinders in their eyes. Should this road use the New, the Greenbrier, and the James in this way, supplemented by central steam power stations, if necessary, there would be no question as to how most people from west of the Appalachians would reach the capital of their country.

In this connection I take pleasure in saying that the C. & O. R. R. has shown great interest in the work, and has given very material assistance. If future appropriations permit, the work will be ex-

tended to cover the entire State; and since the results will benefit no interest so much as the railways, it is hoped and believed that the other railways will help in collecting trustworthy information about the water powers in the sections through which they run.

As to the use to be made of the work that is now being done, I can best explain by supposing a manufacturer to be looking for cheap power. He finds a site, has the available fall measured at that point, and wants to know the quantity of water. If he is on a stream that we have measured and recorded—that is if he is at or near one of our stations—we can furnish him the water power for each day in the year for several years.

Should he not be on one of the measured streams, but on a tributary, he has one measurement made, then the Geological Survey will tell him what the variations through the year will probably be; assuming that streams flowing from similar catchment basins will vary with the rainfall in each. If the rainfall is about the same in each basin, the assumption may fairly be made that the tributary will vary as the main stream does. Similar catchment basins means that the geological formations shall be the same or nearly so.

It is proposed to extend this branch of the work of the Geological Survey by making at least one measurement of each river or creek that may be useful for water power at as nearly low water mark as possible. This will give the critical point in regard to each stream, and the low water ratios being established, the other stages may be estimated with sufficient accuracy for practical purposes.

In conclusion I will say that the Geological Survey will be glad to get the record of any fairly accurate stream measurements that have been made, or any other trustworthy information in regard to the water power of the Virginias.

PROGRESS OF THE AMERICAN PORTLAND CEMENT INDUSTRY.

By Robert W. Lesley, Associate Am. Soc. C. E.

[Read before the Boston Society of Civil Engineers, November 20, 1895.*]

In order to properly give some idea of the Portland Cement Industry in the United States, it seems to be wise, though, to so intelligent a body as I see before me, almost unnecessary, to go into, in a brief way, the distinction between natural and Portland cements, and to give generally an idea of exactly what is meant by those terms when used in connection with cements. So also, while the history of the manufacture of cement in the world dates back to the Roman days, and is no doubt familiar to you all, yet in considering the latest and newest developments in this industry in possibly the largest cement consuming country in the world, a few words upon the history of cement, both natural and Portland, may not be uninteresting.

To begin with, therefore, I would say generally that cements are divided into natural and Portland cements. A natural cement is, as its title implies, a cement formed by nature; that is to say, certain argillaceous limestones, containing varying percentages of lime, silica and alumina, are quarried and without further manipulation are, in their natural condition, calcined in open lime-kilns at low temperatures The resultant product when ground to powder is the natural cement found on the market. In order to illustrate just what is meant by natural cement, a natural cement rock of the Lehigh County, Pennsylvania, district may be taken as a sample. The rock in question, which is of a laminated character, shows to the naked eye, and much more so under the microscope, various laminæ or leaves of varying material; for practical purposes, it may so happen that one of these small layers is lime, another alumina and another silica, or there may be a large layer of lime, two layers of silica together and a small layer of alumina. As can be readily understood, this rock, when calcined under either high or low temperatures, will not under the heat of the kiln, combine in all its elements or parts; consequently for purposes of comparison between natural and Portland cement, it may be broadly stated that from 20 to 25 per cent. of the natural cement is inert or not in combination. This can also be determined by synthesis as well as analysis of material. By taking the portions of silica and alumina that should combine properly

* Manuscript received December 7, 1895.—*Secretary, Ass'n of Eng. Socs.*

with the lime, it will be found that there are certain proportions in excess, and therefore uncombined. These natural rocks are burned at light heat with coal, and when drawn from the kilns are not very hard and are with comparative ease crushed and ground to powder. In this class of cements may be reckoned the well-known cements of the Rosendale, the Potomac, the Lehigh, the Akron, the Louisville, and the Utica districts; all of them excellent in their way, and all of them having been used with success in large work all over the United States.

Portland cement, on the other hand, is essentially an artificial product. While in nature there are found in the Lehigh District, at Boulogne, in France, in Belgium, and in small quantities possibly at one or two other points in the Southwest, natural rocks, which, when calcined at high heat, vitrify and form clinker similar to the ordinary Portland cement clinker, yet experience has shown that owing to the changing of the rocks, the shifting of the strata and the uneven distribution of the chemical elements of the lime, silica and alumina in the mass, they are not to be relied upon to make cement in a large way of uniform grade and reliable character. Therefore, going back to the use of the word "artificial," it was found that to make cement of the uniform character required of Portland cement, that broadly speaking, it was absolutely necessary to make artificially in some way, a new material before the calcining operation. In England, the home of Portland cement, this was done by the original discoverer of this new material by mixing together in a wet way, chalk and the blue clay or mud from the English rivers. In France the same result is achieved by adding to the Boulogne material, sufficient amounts of clay or chalk to bring it to a uniform character, so far as chemical analysis is concerned. In Germany, marls are added to clays, limestones to clays, and in Belgium, lime or clay to natural cement rocks, and also chalk to clay. In all these cases, the broad process has been to mix the two ingredients carrying respectively, first lime, and second, the silica and alumina in a raw condition, with water; the material having prior to that state of the process been reduced to the condition of a fine pulp or powder, according to whether the grinding was in a wet or dry way. The material thus produced, whether by wet grinding in the shape of a cream or paste, or by dry grinding in the shape of a mud, is either allowed to dry, or is dried artificially and is made into bricks, blocks, balls or other forms. This new *artificial stone* as I shall call it, is as you can all see by the foregoing description, composed of finely comminuted particles of lime, silica and alumina, all in close mechanical union, and when of soluble material in many cases in chemical combination. The rock which I take as an illustration is from the Lehigh District. It shows these laminæ of the various ingredients in their natural condition, not in close mechanical or chemical union. The powder pro-

duced by grinding the raw rock shows the same rock, which is practically, by chemical analysis, suitable for manufacture of Portland cement, broken down and distributed into atoms or molecules. The powder is mixed with water and made into the form of bricks. The bricks are made up of small grains of powder which, re-arranged mechanically with the lime, silica and alumina that were formerly in separate laminæ, or not thoroughly mechanically combined, now brought in thorough mechanical combination, and ready in this new form of a *new artificially made rock*, to be acted upon in a chemical crucible. For further illustration may be considered the marl and clay from New York State, which for practical purposes may be stated to represent the chalk and clay of England or the marl and clay of Germany. An examination of the materials will show their marked differences, while an examination of the brick made therefrom will show again a *new rock*, with the elements in close union and ready for the kiln. The kiln therefore, in the process of cement manufacturing, may simply be considered as a large chemical crucible, where the bricks or blocks of the raw material are placed between layers of coke and where under the fierce heat of the kiln the material is brought into a state of incipient vitrification, and the chemical union is formed between the silica and alumina and the lime, forming what may be called double silicates or alumina and lime, though generally speaking, the chemistry of exactly what does happen in the kiln is still an uncertain subject, and many interesting papers and examinations by such chemists as Fremy, Le Chattillier, Feichtinger and Landrin show many varying points of view on this subject. After this calcination, the material which is drawn from the kiln, is in the shape of blackish green masses of clinkers, and while the cement-making material may vary in many parts of the manufacture, the calcined material or clinker is as a generality all about the same color, though slightly varying in weight according to the lightness or heaviness of the materials composing the brick, and the degree of the density of the brick before they are put in the kiln. This may be exemplified by comparing samples of the clinker which is made from the marl and clay material, and that made from cement rocks and limestones.

The grinding of Portland cement is a much more difficult matter than the grinding of natural cement. It requires larger grinding machinery as well as greater grinding power. This is due to the difference in the texture of the Portland cement clinker and of the stone of the natural cement after calcination.

While what I have stated may seem somewhat unnecessary to so well posted an audience, it nevertheless will convey, by means of an object-lesson with the materials before you, just exactly what is meant by the two definitions of cement that we are all using, and in many cases

possibly without much thought as to exactly what is meant by them. So much, therefore, for the definitions of cement.

As to the history of cement, we all know that long before any of us were born or even thought of, the Romans had some sort of a mortar made from combinations of lime and volcanic dust, which was left for one or two years in the shape of a paste made with water, and after it had thus thoroughly seasoned in pits or vats was used in the work that the ancients did in the way of masonry. Little new information on the subject of mortars was developed in the world from that time until the reign of Louis XIV, of France, when a new method of making mortar by the use of lime hot from the kilns was brought before him, in the shape of a petition or address for recognition of this new discovery.

In 1756, Smeaton, who in 1791 described his experiments when writing of his construction of the Eddystone lighthouse, first developed the thought which led to the discovery of the ingredients of hydraulic mortar, and he laid down the principle that the hydraulicity of a limestone depends not, as was formerly thought, upon its color or its texture, but upon the percentage of clay entering into its chemical composition. This discovery naturally caused a general examination by engineers and others of various limestones and other materials in England. Almost contemporaneous with Smeaton's publication came the patent of Jos. Parker, who claimed to make Parker's cement out of certain stones or argillaceous productions. This patent he followed up in 1796 by a second patent for the use of the nodules or "noddles" of clay which he found along the Kentish coast of England. To this cement, later on, the name of Roman cement was given, and it commanded quite a large market in England. Almost contemporaneous with the work of Parker, but still following Smeaton's great discovery, Lesage, who was connected with the French army, found similar pebbles or noddles at Boulogne, out of which he made good quick-setting cement along in 1796. Chemically speaking, all these cements so far mentioned were natural cements, and analyzed very near alike, containing about 45 of lime to 30 of silica and alumina. In France also, Vicat, whose work on mortars for construction, limes for construction, betons and ordinary mortars was published in 1818, had followed up Smeaton's discovery, of the advantage of clay in natural limestone to make such limestone hydraulic—by producing artificial hydraulic limes, by mixing with rich lime varying percentages of clay, doing what he describes in his book when he says, "We have no longer therefore to attend to laboratory experiments, but indeed to a new art, very nearly arrived at perfection." This new art, which he describes in 1818, was what is now the art of making Portland cement, though he did not describe it by that name, nor did he in his early experiments arrive at the final results which he

subsequently attained. At or about the same time that Vicat was experimenting, Jos. Aspdin, a bricklayer of Leeds, England, was carrying on, in a less scientific way, a similar line of work which resulted in 1824 in his taking out a patent for an improvement in the mode of producing an artificial stone, which patent is generally recognized as the first description of the process of making Portland cement, though in point of fact neither the Aspdin patent, nor that of Frost, nor St. Leger, which were taken out in England at or about the same time, would actually make the Portland cement of the present day, because a careful examination of these patents shows that they fail to state that it is necessary to carry the calcination to incipient vitrifaction, though possibly this fact may or not have been withheld as a trade secret, for in the early days of the cement manufacture in England, the business was invested with the greatest amount of secrecy. As a bit of cement history it may be here stated, that in the face of the greater cost of producing Portland cement, the reputation of the English natural cements was so great that for several years after the establishment of Portland cement works the natural product commanded a higher price than the artificial one. It may be interesting, also, to know, in connection with all this business of Portland cement making, that as a general fact, in nearly every case, the large cement works of the world all owe their origin to patents of some kind. The great English works of J. B. White & Co. on the Thames, of Francis & Co. on the Thames, may be traced to the Frost patent of 1822; the cement works at Wakefield, England, which were established in 1825, and which still are in existence, grew out of Aspdin's patents, while other works on the Thames and at New Castle grew out of discoveries of a son of Jos. Aspdin and of a foreman of one of the original works started at the time of the Frost patent. This is especially the case with the Portland cement works of the United States. The spread of the cement industry into Belgium through a son-in-law of Aspdin, and thence into Germany, is not of much historical interest, except so far as it may be stated that Germany to-day is the largest producer of Portland cement in the world, and possibly the most scientific manufacturer. The French exploitation of cement manufacture came out of the inventions of Vicat, followed by the discoveries at Boulogue-sur-mer, at Vassey and at Tiel.

Having thus defined the character of the cements of commerce and briefly given a history of how, within the last hundred years, these two great elements in the building industry were discovered and brought before the public, I think the time has come to say something of what I think is the most interesting subject, and that is the development of the manufacture of cement in the United States. This history, in its incipient stages, almost synchronizes with the history of the development

of the great artificial water-ways or canals of the United States. When the Erie Canal was built, hydraulic mortar was a prime necessity, and out of that necessity grew the discovery of cement-making material near Fayetteville, N. Y., in 1818, and near Lockport, N. Y., in 1824. Natural cement is still made in these two districts, which are known as the Onondago Co., N. Y., and the Akron, N. Y., districts, though the distinct Akron District was not actually opened until some years later. The construction of the Delaware & Hudson Canal, from Rondout on the Hudson to Honesdale, Pa., brought about the discovery of the Rosendale District, where nearly 3,000,000 barrels of natural cement are annually produced, and which district was first opened in 1826. The Louisville District owes its discovery to the Government Canal which was commenced in 1829, for the purpose of facilitating navigation around the Falls of the Ohio at that point. Nearly 2,000,000 barrels annually are the output of that district, which ranks second only to the Rosendale field. When, in 1836, a canal was to be built to connect the coal and mountain district of Maryland with tide-water at Georgetown, necessity, that universal mother of invention, again led to the discovery of cement at Cumberland and at Round Top, the present centers of what is known as the Potomac Cement District. The well-known cement of the West, produced in the Utica, Ill., District, was discovered in 1838, for the purpose of supplying cement for the Illinois and Michigan Canal, which was then building locks and bridges in that vicinity. To the building of canals, again, are due the construction of cement works at Balcony Falls, Va., which cement went into the construction of the Richmond & Allegheny Canal, and the works at Siegfried, Pa., the pioneer mills in the Lehigh Valley District, are due to the construction of the Lehigh Canal.

In addition to these natural cement works, due to the construction of canals, may be mentioned the large mills at Milwaukee, on the lake and rail, and the works at Cement, Ga. All these cement works produced in the year 1894, nearly 8,000,000 barrels of natural cement, and, as showing the effect of competition in this industry, it may be stated that in 1884 a product of just about one-half the number of barrels yielded as many dollars as the entire product of 1894.

The quarries of all these natural cements vary largely in their character, some being mines and other open-face quarries. The rock in some cases is crystalline and in others laminated, and the chemical constituents vary largely between argillaceous limestones and argillaceous dolomites; in either case the process of manufacture is about the same and is similar to that described above. There are differences, of course, in the character of materials and analysis, but they are almost insignificant, and the process in the manufacture of natural cement

shows very little change from the date of its earliest establishment in this country, though the quality has improved largely and the cements have obtained a great and well-deserved reputation for uniformity and durability.

The reputation of Portland cement in Europe, established by its use in the London Sewage Department under John Grant, and by its extensive use on docks and other public work all over Europe, soon reached America, through engineering publications and through the practical knowledge engineers had of it, who came from Europe to this country to engage in large engineering work here. As far back as 1865 it was an article of importation, and was used sparingly for side-walks and the more difficult character of engineering works. The imports were small, and the article being one not generally known, prices were large and the business limited. Attention, however, was called to the material by the steady growth of the imports and by the general acceptability of this new article of trade. Work was done with it which could not be done with natural cement, and most excellent results were obtained. American ingenuity, always ready to seek new outlets for its labor and for its capital, soon began studying the manufacture of Portland cement. At Wampum, Pa., on the Allegheny River, near Pittsburg, Pa., cement works were established for the manufacture of Portland cement from limestone, in the early seventies. The location was admirably adapted for the business; the material being on the ground and a seam of coal being in close proximity. Under the management of a Mr. Shinn, Portland cement of excellent quality was produced, and was exhibited at the Centennial World's Fair, in Philadelphia, in 1876. These works are still in existence, are owned by the National Cement Co. of Pittsburg, and while they have not been largely increased, are still doing business. At about the same time, Mr. D. O. Saylor, in association with Mr. Esias Rehrig and Adam Woolever, of Allentown, Pa., came to the conclusion that a Portland cement could be made from the natural cement rocks of the Lehigh Valley, which they at that time were manufacturing into what was known commercially as "Anchor" natural cement. Mr. Saylor's first idea was that he could take these natural rocks and burn them at high temperatures to incipient vitrifaction, and by grinding that product make Portland cement. The first results justified his expectations—the rock did clinker; did resemble Portland cement clinker, and when ground and made into briquettes gave results on the testing machine equal to the best imported brands. He manufactured a large quantity of it, but suddenly found he was doomed to disappointment, for the material, owing to the irregularities in the laminæ of the rock, was not homogeneous, and at long periods the briquettes, pats, and work made with the cement, all began to fall away

and disintegrate. At that time he had a large stock of this cement in bins, and was driven to his wits' ends to know what to do with it. He put his brains to work; had analyses made of his rock; found that the analysis was near the Portland cement of commerce, and without anything but his native wit to guide him, ground the raw material into powder, made the powder into brick, sent to England for designs of the kilns then in use on the Medway and Thames, and actually made Portland cement, and, strange to say, when later he came to look at the bins of damaged cement he had on his hands, he took lumps of that material which had hardened in the bins, and, by re-calcining to clinker, made excellent Portland cement. Cement of this manufacture was also exhibited at the Centennial Exposition of 1876, where both Portland cements, the Wampum and the Saylor, held their own with the foreign brands then exhibited. Mr. Saylor was assisted in his work by Mr. John W. Eckert, a graduate of Lehigh University, who was for many years his manager, and who subsequently became President of the American Cement Co., at Egypt, Pa., in close proximity to Saylor's works. The works erected by Mr. Saylor are still in existence under the name of the Coplay Cement Co., and make excellent Portland cement, which is sold as "Saylor's Portland Cement."

In the Rosendale District on the Hudson, a number of gentlemen undertook to make Portland cement out of Fuller's earth and lime, under patents of C. F. Dunderdale. Works were erected, but it was found that the cost was so far out of proportion to the price that could be realized, that these works, which were established in 1876–77, were finally abandoned, as were other similar works subsequently established under the name of the Walkill Portland Cement Co., in the same district.

The Buffalo Portland cement, of which small quantities were manufactured for a few years along from 1878 to 1885, was due to the discoveries and patents of Uriah Cummings and L. J. Bennett, who were connected with these works, and who found by selecting the overburned material from the common cement kilns of the Buffalo Cement Co., a material resembling Portland cement could be made. The rock, however, was largely magnesian, and for this reason no great quantities of Portland cement were made.

The next large development in the manufacture of Portland cement in this country grew out of patents issued to E. J. DeSmedt, J. M. Willcox and R. W. Lesley, during the years 1883, 1884, 1885, and the co-operation with these gentlemen, of Mr. John W. Eckert, who, as already stated, had been one of the pioneers in the manufacture of Saylor's Portland cement at Coplay. The American Cement Company was the outgrowth of this combination, and is to-day the largest manufacturer

of Portland and Improved cement in the United States, and one of the largest manufacturers of natural hydraulic cement. Its original mill, the Egypt Portland Cement Works, was started in 1884, at Egypt, Lehigh County, Pa., and is still a large producer of Portland and other cements. Near by, it has been supplemented by two other large works, under the same management, the Pennsylvania Portland Cement Works, and the Columbia Portland Cement Works, while a fourth works, owned by the same company, is at Jordan, Onandago County, New York, just beyond Syracuse. The first three of these works manufacture Portland cement from natural rocks and lime, while the Jordan works produces its Portland cement by an admixture of marl and clay. The machinery in all these mills is of the most approved character, both for burning and grinding, and four Corliss engines of 600 horse-power each, one Naylor engine of 300 horse-power, and another Corliss engine of 125 horse-power, supply the motive power to drive the machinery.

The cement produced at these mills is known as "Giant Portland Cement" and has been used largely on public work all over the United States.

About the same time that these works were being established Portland cement was manufactured in a small way at Rockland, Me., by the Cobb Lime Co., but owing to the cost of fuel the manufacture was discontinued. As an outgrowth of patents of J. Murphy and N. Lord, Portland cement works, which are still running, were established at Columbus, Ohio, about 1885, for the manufacture of Portland cement from slag, lime and clay. In Texas; at about the same time, the Alamo Portland Cement Works were established at San Antonio, and produced cement from an admixture of a natural cement rock and a species of chalk there found. Chicago also entered into the business, and attempted to make a commercial Portland cement by importing Portland cement clinker from Europe and grinding it up with raw limestone to produce a commercial artificial Portland cement; while Louisville, not to be outdone, inasmuch as all the other natural cement districts were experimenting with Portland cement, undertook, under patents of Anderson & Brice, to make Portland cement by calcining, at high temperatures, small pieces of magnesian rocks and also by combining limestone and marl and shales for the same purpose. Colorado also was not behind-hand, and works were established there for the purpose of making cement at Colorado Springs, and also at Denver, out of the sulphate of lime rocks found near Manitou. One of these works was in existence until last year, when it was burned down. Two Englishmen undertook to manufacture cement under the English process, and established themselves in the early eighties at South Bend, Ind., where they were quite successful in manufacturing cement out of

marl and clay, and founded a works which is still in existence. Subsequently, these gentlemen, the Messrs. Millen, were the pioneers in opening up the marl and clay deposits around Syracuse, where they established works which are now the Empire Portland Cement Works, which they subsequently sold to build new works for themselves further west, at Wayland, N. Y. All these works manufacture cement practically under the same general process, though of different materials, ranging all the way from natural argillaceous limestones down to mixtures of clay and marl. All of them use the same general form of kiln such as are used on the Thames and Medway in England, and on the Rhine in Germany, and all of them vary slightly in the character of their grinding machinery. Other Portland cement works, manufacturing cement under these same methods, are located at Siegfried and Whitehall, Pa., at Bellefonte, O., at San Diego, Cal., and at Yankton, South Dakota.

At about the same time the American Cement Company were getting under way at Egypt, new experimental works were started on the Hudson by Jos. F. De Navarro and others operating under patents granted to Henry Mattey about the years 1885-86. These patents were for roasting small pieces of natural cement rocks in rotary kilns, and calcining them to incipient vitrifaction at the great heat produced by petroleum vapors injected into the rotating cylinders. The works on the Hudson, by reason of the non-adaptability of the materials, proved a failure. The particular form of kilns also were unsuccessful, but subsequently by adopting kilns and processes under inventions of Ransome, of England, the process of making cement in rotary kilns began after its removal from the banks of the Hudson to Coplay to take on a moderately successful aspect. The calcination of gypsum in revolving cylinders had been done under the Smith process in Philadelphia with excellent success, and Ransom's process was the application of this theory to another material. Works were established in 1886, on the Lehigh River, Pa., and are to-day manufacturing a large quantity of Portland cement under the name of Atlas Portland. Other works operating under different methods, but still making Portland cement under the rotary process, are in existence at Whitaker, N. J., and at Vulcanite, N. J., under the names, respectively, of the Alpha Portland Cement Co., and the Vulcanite Portland Cement Co. The cements made under this process generally carry admixtures of 2 to 3 per cent. of calcined plaster to counteract the quick-setting properties produced by their calcination, and they have not been in the market for a sufficient period of time to thoroughly determine their permanence and endurance. This, roughly speaking, is the history of the American Portland cement industry, which to-day gives employment to about 2,000 men, has 20 works, and manufactures about 800,000 barrels per annum.

From an engineering standpoint the question of the use of American Portland cement is naturally a serious one, inasmuch as the reputation of the engineer is measurably dependent upon the permanence and stability of the work he constructs. In this connection it is a satisfaction for the American manufacturer to be able to point to such records as will eliminate from the mind of every fair-minded engineer any questions he may have as to the character of the materials which established manufacturers in this country seek to have him use.

In the first place, let us consider what are the means of determining what a good Portland cement is, and what are the requirements generally adopted for the determination of such qualities. The first method is the testing for fineness and tensile strength. This testing may be for short or long periods, but the most convincing proof to the engineer, and far more conclusive than any of the ordinary seven and twenty-eight day tests that are usually used, and which in thousands of tests made by the best engineers show results equal to any foreign cement, is afforded by a table which will be found below, showing records on 300,000 barrels of American Portland cement, used on five of the most important pieces of work done in the United States, and carried out to a period of five years, showing continuous gains in the neat and sand tests made in the laboratory, and continuous gains in all the sand tests taken from the mortar boxes actually in use during the construction of the work. This table, which contains what is believed to be the only long-time records on Portland cement in the world for similar quantities and for as many different pieces of work, bears the most conclusive evidence as to the scientific side, as well as the practical side of testing Portland cement, and the results shown are certainly conclusive as to the reliability, permanence and stability of the American Portland cement, especially as the works on which the cement was used bear practical evidence to the same excellent qualities.

The second method of testing cement is by chemical analysis, to determine the constituents of the material and to ascertain whether it is properly proportioned, and whether it has an excess of the deleterious elements of sulphate of lime and magnesia. Analyses by such experts as Reid, Michaels, Redgrave, Candlot, and others, may be taken as standards of what the leading scientists think are about the requirements of a good Portland cement, and analyses of American Portland cements made by such experts as De Smedt, of Washington; Faija, of London; Booth, Garret & Blair, of Philadelphia, show that the American Portland cements, made in the standard way, compare favorably in all their elements with the analyses of the best foreign brands, as made by the best foreign experts. In conclusion, it may well be asked what the American manufacturer has to show, outside of chemical and scientific

Long-Time Tests.

Tests of over Three Hundred Thousand Barrels "Giant" Portland, on five of the largest dams in the United States; on the Niagara Falls Power-Tunnel, and the Reading Terminal Railroad and Station, in Philadelphia, for periods up to five years.

The only records of long-time tests on Portland Cement now published in the United States.

BRAND "Giant" Portland	Mode of Mixing.	1 Day		1 Week		1 Mo.		3 Mos.		6 Mos.		9 Mos.		1 Year		15 Mos.		18 Mos.		2 Years		3 Years		4 Years		5 Years		Fineness.		
		Number of Briquettes.	Average, in pounds.	Number of Briquettes.	Average, in pounds.	Number of Briquettes.	Average, in pounds.	Number of Briquettes.	Average, in pounds.	Number of Briquettes.	Average, in pounds.	Number of Briquettes.	Average, in pounds.	Number of Briquettes.	Average, in pounds.	Number of Briquettes.	Average, in pounds.	Number of Briquettes.	Average, in pounds.	Number of Briquettes.	Average, in pounds.	Number of Briquettes.	Average, in pounds.	Number of Briquettes.	Average, in pounds.	Number of Briquettes.	Average, in pounds.	Residue on No. 50 sieve, 2,500 holes to sq. in.	Residue on No. 74 sieve, 5,180 holes to sq. in.	Residue on No. 100 sieve, 10,000 holes to sq. in.
Sodom and Bog Brook Dams, New York Aqueduct. About 50,000 bbls.	Neat	1,025	140	1,398	348	220	422	180	510	100	631	30	638	180	682	30	687	110	672	110	691	90	736	60	771	10	840	......	......	18.0
	2 to 1	...	...	220	466	120	280	140	361	84	468	50	468	90	490	36	526	100	530	100	561	130	680	120	674	20	700			
	3 to 1	....	...	226	440	140	234	112	350	110	428	30	428	240	420	40	500	80	511	80	512	160	572	...	...	10	590			
Titicus Dam, New York Aqueduct. About 100,000 bbls.	Neat	3,448	157	4,165	380	637	476	505	529	478	575	479	599	350	612	181	591	135	581	137	611	62	668	...	...	...	...	......	......	11.7
	2 to 1	....	...	2,934	200	424	317	281	450	321	491	278	532	219	519	157	557	92	511	52	536	37	573							
	3 to 1	....	...	1,604	145	260	185	450	289	133	317	146	311	132	426	70	421	66	416	126	419	7	483							
Carmel and Craft's Dams, New York Aqueduct. About 40,000 bbls.	Neat	1,786	140	1,075	343	324	443	551	517	529	518	491	568	289	617	...	...	273	604	211	611	...	...	...	...	...	...	......	......	11.7
	2 to 1	....	...	1,642	482	216	308	85	445	87	480	76	472	43	585	...	...	49	477	55	475									
	2 to 1 from Mortar Box	....	...	61	161	51	237	8	385	11	491	8	491	7	367	...	...	12	516	3	568									
	3 to 1	....	...	13	100	13	171	7	319	12	372	11	398	10	443	...	...	8	401	10	406									
	3 to 1 from Mortar Box	....	...	45	112	31	166	6	310	8	480	7	500	9	544	...	...	7	437	5	406									
Reading Terminal Railroad and Station, Philadelphia. About 60,000 bbls.	Neat	....	...	329	315	267	376	69	451	15	519	16	576	10	523	1	610	...	...	...	...	...	...	...	...	...	...	.090	10.01	11.79
	3 to 1	....	...	536	79	431	129	104	171	20	228	15	225	47	261	5	287													
	2 to 1 from Mortar Box	....	...	190	81	180	141	17	219	13	231	25	281	62	325	12	417													
Niagara Falls Tunnel, Niagara Power Co. 60,000 bbls.	Neat	....	...	495	321	309	420	12	511	24	562	...	...	24	661	...	...	...	...	...	...	...	...	...	...	...	...	......	......	11.9
	2 to 1	....	...	482	152	271	212	54	369	20	451	...	...	7	472															
	3 to 1	....	...	527	98	399	177	143	251	181	301	...	...	12	391															

tests. It is true that he has shown that his cement meets all the requirements of fineness and tensile strain; that it analyzes the same as the best foreign brands; but this is not all that should be properly asked of it. He should show where his cement has been used, and, therefore, as the "proof of the pudding is in the eating of it," the American manufacturer is enabled to point to the engineer as evidence of the character and stability of his product to the fact that it has been used on such important work as the Eads Jetties at New Orleans; the Cornell, Sodom, Bog Brook, Craft's, Carmel and Purdy's dams of the New York aqueduct system; on all the dams of the great East Jersey water system; on all the dams of the Scranton Water Co. system; on the St. Louis Water Works; on the Chicago Elevated Railway; on Government Post Office buildings at Washington, Buffalo, and other cities in the United States; on the Manhattan Life Building, Waldorf Hotel, Germania and Hanover Fire Insurance buildings, Wool Exchange, Coffee Exchange, and other large buildings in New York; on the Drexel Building, Drexel Institute, Harrison Buildings, Odd Fellows Temple, Girard Estate Buildings, Girard Trust Co. Building, Williamson School, House of Refuge, and other large buildings in Philadelphia; on the large new East River Bridge and Third Avenue Bridge, New York; on the New London bridge, over Thames River, Conn.; the celebrated Johnstown Bridge of the Penna. R. R.; new Delaware River bridge of the Penna. R. R.; and on many small bridges of the Pennsylvania, Philadelphia & Reading, Lehigh Valley, Baltimore & Ohio, Delaware, Lackawanna & Western, and New York Central Railroads; on the greatEast River Gas Tunnel, New York; on all the work of tunnels, power-house and other buildings of the Cataract Construction Co., at Niagara Falls; on the Niagara Power Co., Niagara Falls, N. Y.; on the cable and underground electric roads in Pittsburg, New York and Philadelphia; on the Jersey City Terminal and Station, Jersey City; and on the bridges, approaches and new Broad Street Terminal and Station of the Pennsylvania Railroad, Philadelphia; on the Terminal and Station of the Philadelphia & Reading R. R., Philadelphia; on the Allentown and Easton, and other stations of the Lehigh Valley R. R. and Philadelphia Station of the Baltimore and Ohio R. R. It is on evidence such as this that the American Portland cement manufacturer, with his works, capital and labor in this country, bases his claim to the consideration of engineers, and points to as proof of the progress of the Portland cement industry in the United States.

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STRENGTH OF BRONZE IN COMPRESSION.

BY S. BENT RUSSELL, MEMBER OF THE ENGINEERS' CLUB OF ST. LOUIS.

[Read before the Club, October 16, 1895.*]

IN certain kinds of machinery, where the wearing parts are exposed to conditions which would cause corrosion of iron or steel, the engineer often finds it economical to make these parts of bronze, or to line them with bronze or other alloy. This is especially the case where the mechanism has periods of idleness while the parts are exposed to the corroding conditions.

A good example of such machinery will be found in sluice gates, water and steam valves, etc. Such gates and valves are frequently operated by screws, and it was the designing of such screws and similar members which led to the tests herein given. The writer has at times had occasion to design gate stems over 3 inches in diameter, and others having a travel of as much as 6 feet.

Now, in designing a screw stem to be operated by hand-power, it is desirable to make the diameter as small as may be, so as to reduce the friction to a minimum.

The work in foot pounds needed to overcome the friction of the thread under a given load and with a given "pitch," is in direct proportion to the distance through which the thread has to travel. This

* Manuscript received December 13, 1895.—*Secretary, Ass'n of Eng. Socs.*

distance is, of course, proportional to the diameter of the screw. Hence, as stated above, the smaller the screw the more easily it will be operated.

In the case of piston rods too, smaller diameters make smaller stuffing boxes and less friction. Moreover, bronze is very expensive compared with iron, so that true economy calls for careful designing. Gate stems and piston rods, when properly designed, will fail in compression rather than in tension. What the designer needs, then, is a rule or rules for finding the strength of bronze columns. On the other hand, while many tests of bronzes in tension have been made and published, very little study appears to have been given to the strength of bronze in compression.

Table I.

TENSION TESTS OF BRONZE.

	Laboratory Number.	Diameter.	Breaking Strength in Pounds per Square Inch.	Proximate Elastic Limit, Pounds per Square Inch.	Per cent. of Elongation.	Per cent. of Reduction of Area.	Modulus of Elasticity in Pounds per Square Inch.
Tobin Bronze . .	486*	1.250	66180	53000	36.3 in 4 inches		
" . .	487†	1.049	68880	. . .	. . . .	22.9	
" . .	490	0.872	62480	49400	31.2 in 6 inches	44.4	
" . .	520	0.869	63200	. .	31.0 "	44.2	14170000
Phosphor Bronze .	488	1.000	28540	15900	12.7 "	20.1	
" .	521	1.000	28690	. . .	14.0 "	15.9	10510000
No. 85 Composition	489	1.000	30060	12000	12.0 "	19.1	
"	519	1.000	30060	. .	11.5 "	16.4	10700000

* Broke in grip.
† Stud bolt with thread and nuts.

Enough has been said, however, to show the reasons for making the tests herein described, and to justify the writer in publishing this article.

Consulting well-known authorities we learn that to arrive at the strength of a column we must have the compressive *strength of the material*, and also the elastic limit and modulus of elasticity. In long columns the rigidity of the material is a very important factor.

Not being satisfied with the data obtainable in books of reference, the writer was impelled to order the tests herein described.

Three kinds of bronze are now in general use by the Water Works Department of St. Louis, viz.:

Tobin bronze, which comes in rolled rods. Phosphor bronze, which may be cast in any form. And thirdly, a composition, made of 85 parts of copper, 10 parts of tin, and 5 parts of zinc, which also may be cast in any form.

To prepare for the tests, 11 or 12 test-bars of each kind of metal were obtained. To show the quality of the metal by ordinary stand-

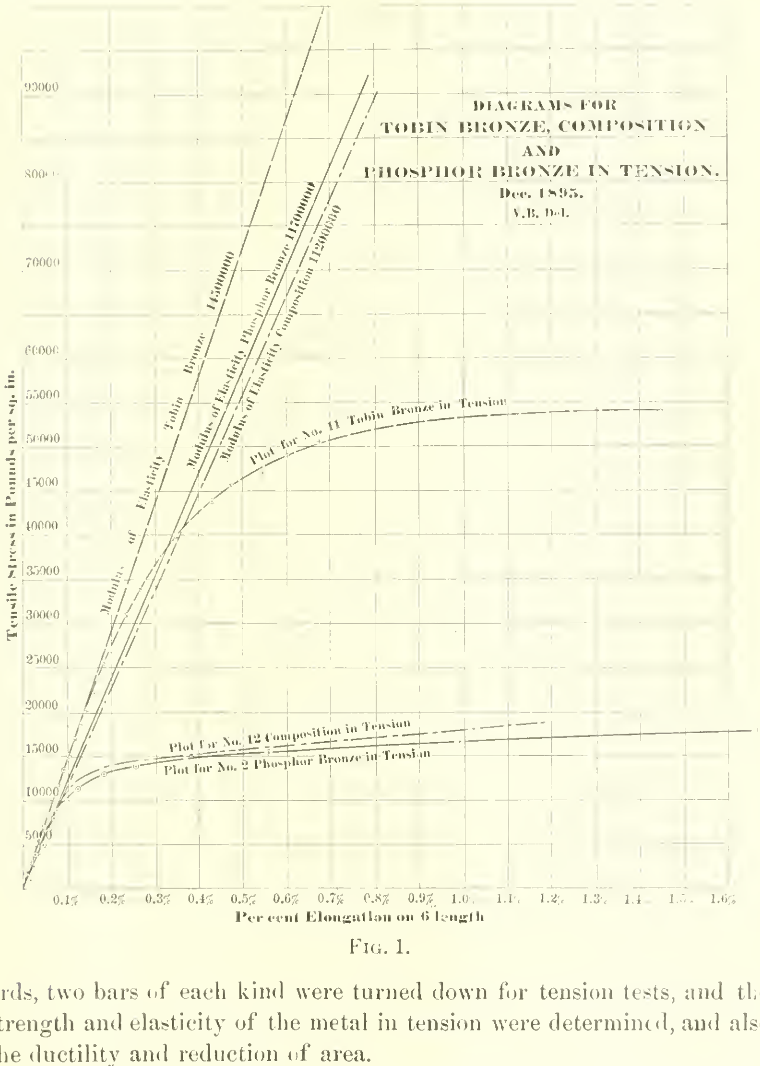

FIG. 1.

ards, two bars of each kind were turned down for tension tests, and the strength and elasticity of the metal in tension were determined, and also the ductility and reduction of area.

The remaining test-bars which were all 1¼ inches in diameter and 15 inches long, were tested in compression to failure. The Tobin bronze

TABLE II.

SUMMARY OF TESTS OF BRONZE BARS.

Kind of Bronze.	Kind of Stress.		Number of Tests.	Ultimate Strength in Pounds per Square Inch. f.	Number of Tests.	Proximate Elastic Limit, Pounds per Square Inch.	Number of Tests.	True Elastic Limit, Pounds per Square Inch. p_0.	Number of Tests.	Modulus of Elasticity, Pounds per Square Inch, E.
Tobin Bronze.	Tension.	Maximum.		63200						
		Minimum.		62480						
		Average.	2	62840	1	49400	1	20200	1	14170000
	Compression.	Maximum.		43760		40800		13880		15410000
		Minimum.		40820		33400		12240		15020000
		Average.	9	42520	7	36210	2	13060	2	15215000
Phosphor Bronze.	Tension.	Maximum.		28540						
		Minimum.		28090						
		Average.	2	28315	1	15900	1	8900	1	10510000
	Compression.	Maximum.		19100		17100		8800		14200000
		Minimum.		17710		16700		8600		13980000
		Average.	10	18360	8	17000	2	8700	2	14090000
No. 85 Composition.	Tension.	Maximum.		30060						
		Minimum.		30060						
		Average.	2	30060	1	15300	1	11500	1	10700000
	Compression.	Maximum.		18450		16300		9800		12410000
		Minimum.		17630		15500		9400		11760000
		Average.	9	18070	7	15950	2	9600	2	12085000

samples were simply cut from rolled 1¼ inch rods, while the others were cast and turned down to 1¼ inch; all were cylindrical, with flat ends.

Two compression bars of each metal were tested carefully with an extensometer, so as to obtain a strain diagram.

Table I shows the results of the tension tests, and this table, with

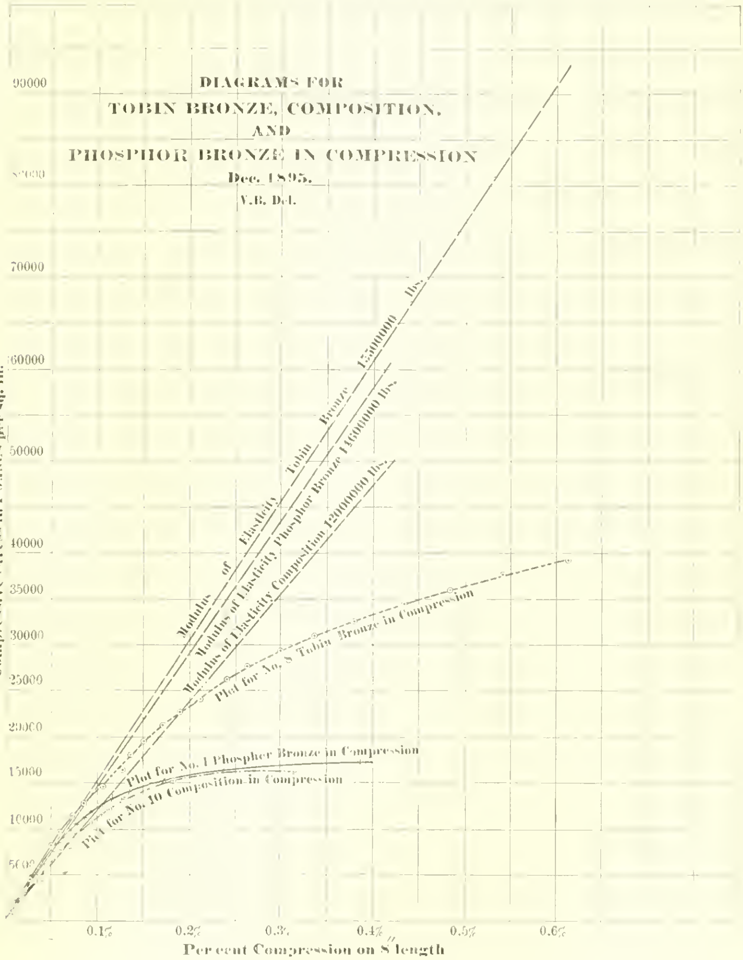

FIG. 2.

the strain diagrams shown on Figure 1, gives a complete report of the tests made in tension.

Table II gives a summary of all the tests of the three metals, both in compression and tension, and is, we may say, the important feature of this paper.

In both of the above tables, the writer has used the expression "prox. elastic limit," to signify the point at which the stretch or compression of the bar can be observed with the dividers. This point has been known as the "elastic limit" by some, and has been termed the "yield point" by others, to distinguish it from the true elastic limits which in many materials can only be determined by a study of the strain diagram.

Figure 2 gives one strain diagram of each metal in compression. In each case, the two diagrams of the same metal were practically identical, hence, to reproduce them all would add nothing to the reader's profit. A glance at this plate will give a good idea of what difference there is in the nature of the three metals.

As these bars were only 12 diameters in length, and had flat ends, they may fairly be considered as short columns. The results obtained directly from these tests may be used for short columns, and will probably be of value to the designer.

The reader will note the difference between these strain diagrams and those given by wrought iron and steel which show a well-defined yield point. It is noteworthy too that the difference between the slope of the line at the true elastic limit and the slope at, or rather just below the "prox. elastic limit," is more marked in the case of these alloys than it is in the wrought iron or steel strain diagram.

In connection with the observed facts herein described it was thought proper to furnish some deductions showing the strength of long columns of bronze. In the absence of direct experiments on long columns the designer must be content with the probable values obtained by the use of more or less rational formulas.

For very long columns the maximum load can be definitely determined by the use of Euler's rational formula.*

$$p = \frac{\pi^2 E}{\left(\frac{l}{r}\right)^2}$$

When $p =$ safe load of column in lbs. per sq. in.
$E =$ modulus of elasticity in lbs. per sq. in.
$\frac{l}{r} =$ length of column divided by least radius of gyration.

Plotting the maximum load and the $\frac{l}{r}$ as co-ordinates we obtain a curve which is applicable whenever the maximum load per square inch of section falls below the true elastic limit of the material.

We now know the strength of short columns and the strength of very long columns. It only remains to find the strength of columns of medium length.

* All columns are assumed to be symmetrical in cross-section and symmetrically loaded.

To do this the writer has made use of a modification of the well-known Gordon formula so as to obtain a curve which would agree with Euler's formula at the true elastic limit, and would agree with the observed strength of short columns when $\frac{l}{r} = 0$.

TABLE III.

BRONZE COLUMNS—FLAT ENDS.

Data used in computing Table IV.

	Ultimate Strength, Pounds per Square Inch. f.	True Elastic Limit. p_o.	Modulus of Elasticity. E.
Tobin	42500	13000	15000000
Phosphor	18000	9000	14000000
No. 85 Composition	18000	9500	12000000

TABLE IV.

ULTIMATE STRENGTH OF BRONZE COLUMNS WITH SYMMETRICAL SECTIONS AND SYMMETRICAL LOADING.

Flat Ends. $\frac{l}{r}$	p. Pounds per Square Inch. Tobin.	Phosphor.	No. 85 Composition.	Pivoted Ends. $\frac{l}{r}$	Cylindrical Columns with Circular Cross-Sections. $\frac{l}{d}$* Flat Ends.	Pivoted Ends.
1	2	3	4	5	6	7
24	42400	18000	18000	12.	6.	3.
40	41800	17900	17900	20.	10.	5.
48	41400	17900	17900	24.	12.	6.
56	40700	17800	17800	28.	14.	7.
64	39900	17700	17600	32.	16.	8.
80	37700	17400	17300	40.	20.	10.
106	32800	16700	16400	53.	26.50	13.25
120	29700	16200	15800	60.	30.	15.
140	25300	15300	14700	70.	35.	17.50
160	21100	14200	13500	80.	40.	20.
180	17400	13000	12200	90.	45.	22.50
200	14200	11800	10900	100.	50.	25.
213	12500	11000	10100	106.50	53.25	26.60
223	11300	10400	9500	111.50	55.75	27.90
248	8870	9000	8070	124.	62.	31.
280	6580	7380	6500	140.	70.	35.
300	5510	6500	5660	150.	75.	37.50

* $\frac{l}{d}$ = length measured in diameters.

It is not necessary here to go into a mathematical discussion on column formulas. There is, however, a way of testing such a curve mathematically which will show it to be near enough to the ideal curve for all practical purposes.

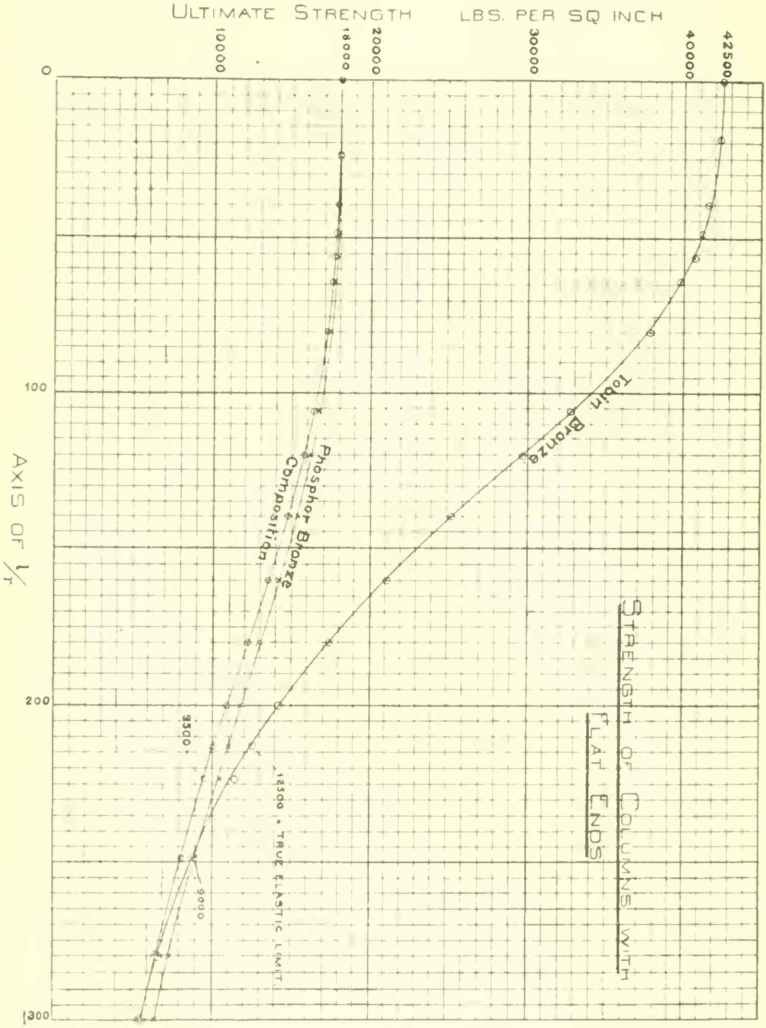

Fig. 3.

From such formulas the values given in columns 2, 3 and 4 of Table IV were computed, using the data shown in Table III. Plotting the values of p obtained from the formulas to the corresponding values of

the ratio $\frac{l}{r}$ we get the curves shown on Figure 3. The strength of a column with pivoted ends may be taken as equal to the strength of a flat-end column having twice the length.

In using the diagram (Figure 3) and Table IV, the designer should of course keep in mind that the values given are obtained by deduction from the strength and elasticity of short columns, and should use whatever factor of safety his judgment dictates. In the case of the Tobin bronze it is well to remember also that smaller rods require more rolling and are usually tougher than large rods.

It is interesting to note from the diagrams and tables that short columns of Tobin bronze are much superior to similar columns of the other metals. For very long columns, however, the metals show nearly equal strength.

The principal value in the deductions herein given comes from the fact that they are based on experiments with true short columns, and not on the crushing strength of cubical or nearly cubical specimens.* Figure 4 is given herewith to show the shape after testing of the small columns used in the experiments.

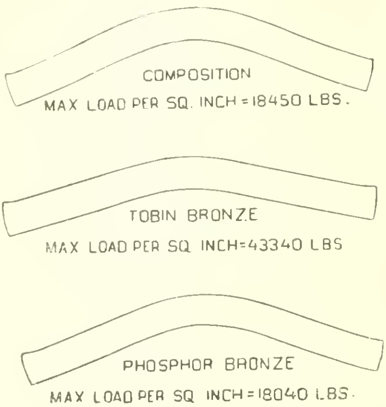

Fig. 4.

* In the discussion of the paper Prof. J. B. Johnson called attention to the fact that the crushing strength of a specimen nearly cubical in form, of metal like bronze, copper or lead, is in reality indeterminate, as the material will flow without true crushing.

THE PRESENT EUROPEAN PRACTICE IN REGARD TO SEWAGE DISPOSAL.

By Allen Hazen, Member of the Boston Society of Civil Engineers.

[Read before the Society, October 16, 1895.*]

The countries of western and central Europe have a denser population than is the case with the greater part of the United States, and although their cities are growing, in many cases, almost as rapidly as ours, there have been for many years in Europe centers of population which compelled attention to various sanitary questions long before corresponding issues were raised in the United States, and processes of sewage purification have been in common use in Europe, particularly in England, for the last quarter of a century, which are just beginning to be seriously considered and adopted in the United States.

It is of course true that a certain amount of work, particularly experimental work, has been done in the United States which is of as high a grade as that which has been done anywhere, and some of the information which has been secured in America in regard to sewage purification processes, and the disposal of sewage by dilution in streams and lakes, is of great value to us and could not be replaced by any amount of European experience obtained under other conditions of climate and geology; but on the other hand, the continued experience of European cities for a long series of years with many of the problems which are now seriously confronting American cities has resulted in the accumulation of a fund of information which deserves to be most carefully studied by all who would be proficient in the art and science of sewage disposal.

There are in reality two sewage disposal problems which are radically different from each other in their natures and which present themselves in different cases. The first of these is the case of the discharge of sewage into bodies of water, either lakes or rivers, from which water is taken for domestic supply from points which may be reached by the discharged sewage. The problem presented in this case is to so completely purify the sewage that when mixed with the water it will not be injurious to health. Years ago, before the germ theory of disease was established, the possibility of purifying sewage in this way would hardly have been admitted, but thanks to the more recent German and English investigations, as well as to the experiments of our own [Mass.] State

* Manuscript received December 24, 1895.—*Secretary, Ass'n of Eng. Socs.*

Board of Health, it is now well known that it is entirely possible to accomplish this through the wonderful purifying power of sandy soils under proper conditions; and it is actually a fact that the effluents from certain European sewage works, as well as from some of the purification fields in Massachusetts, are preferable, from a hygienic standpoint, to the public supplies of a number of large American cities.

The second problem in sewage purification is that of so purifying sewage that it will not cause a nuisance in the water into which it flows. When a small quantity of sewage is discharged into a large volume of pure, or comparatively pure water, the organic and polluting matters of the sewage are oxidized and destroyed by the oxygen of the air which is ordinarily contained in solution in the water into which the sewage is discharged. In case, however, the quantity of sewage becomes greater than can be oxidized at once by this oxygen, the last part of the decomposition of the organic matters takes place in the absence of air, and with the formation of products which are given off into the air causing objectionable odors, and the whole body of the liquid becomes foul. The condition becomes still worse when the water is still, or has so low a velocity that it allows the heavier matters from the sewage to be deposited upon the bottom, where they accumulate as masses of mud which decompose with the most objectionable results. This condition of affairs may often result even though the quantity of sewage is not great enough to render the whole body of the water offensive, and is thus likely to occur in sluggish streams which would otherwise remove the sewage without nuisance.

It is undoubtedly a fact that sewage has been purified much more frequently to prevent the production of a nuisance of this kind than to protect the purity of drinking water supplies, perhaps because a black dirty stream, giving off sulphureted hydrogen gas, is more obviously a nuisance than is a polluted water supply, the relation of which to the health of the community is too often but imperfectly realized even by those having such matters in direct charge, and much less by the mass of voters and tax-payers whose support must be obtained before any expensive improvements are possible.

The processes which are used for purifying sewage may be divided into two general classes: land treatment and chemical processes, although a combination of both of them is frequently used. The principles involved in purifying sewage by applying it to land, are essentially the same whether it is applied to soils and loams at a very low rate and with a growth of crops under the name of "broad irrigation," or whether it is applied to specially prepared areas of favorable materials at much higher rates under the name of "intermitting filtration;" and even the filtration at very high rates with forced ventilation, which has recently

been proposed, but has not as yet been carried out on a large scale, involves exactly the same principles.

The other class of processes are those which by chemical and mechanical means attempt to remove from the sewage in concentrate form a portion of its impurities, and although the number of processes which might be included in this general definition is very great, none of them have achieved practical success except such as can properly be called "chemical precipitation."

One of the most interesting cases where sewage is purified to prevent the pollution of public water supplies, is furnished by the cities and towns upon the watersheds from which the water supply of London is drawn. Conservancy Boards have control of the rivers, and it is their duty to see that they are not polluted so as to affect the quality of the water supplies drawn from them, or become otherwise injurious to the people upon their banks. The Conservancy Board of the River Thames has control of the main river for its whole length, and of its tributaries within ten miles of the main river measured in a straight line, but curiously enough, it has no control of the tributaries beyond that distance. The Conservators of the River Lea have control of the entire watershed.

There are thirty-nine places upon these two rivers which are giving their sewage systematic treatment, and, so far as known, no crude sewage is ordinarily discharged into the rivers at any point. Of these thirty-nine places, thirty-eight treat their sewage by applying it to land, while one of the smaller places, Hertford, uses chemical precipitation. The Conservators do not regard the chemical precipitation as satisfactory, and have recently conducted an expensive lawsuit against the local authorities to compel them to further treat their effluent, but this suit was lost, as the court held that no actual injury to health had been shown. It is worth noticing, however, that the water into which the effluent is discharged, is all carefully filtered before it is delivered to consumers.

The Conservators require, where land treatment is used, that sufficient area shall be provided to allow all of the sewage to percolate through it in ordinary weather, and they strongly object to allowing any sewage to flow over the surface of the land into the streams. The land used for this purpose, however, is, as a rule, much less porous than the land commonly used for sewage treatment on Continental Europe and in this country; and at times of heavy storms there is often as much water from the rain alone as the land can take without becoming unduly flooded, and it is then incapable of receiving even the ordinary quantity of sewage, and much less the storm flow, as the sewers are generally, if not always, on the combined system. At such times, the

sewage either flows over the surface of the land with the very inadequate purification due to the retention of solid matter in the grass and osiers, or perhaps more frequently it is discharged directly into the rivers without even a pretense of treatment. The Conservators apparently regard this as an unavoidable evil and do not vigorously oppose it, as it is their theory that at these times the increased dilution with the high water in the rivers is such that there is no great danger from the sewage, although it would seem that the increased velocity and consequent reduction in time for the matters to reach the water-works intakes would, in a large measure, counterbalance the increased dilution.

The water companies are expected to have so much storage capacity for unfiltered water that they will not be obliged to take in water at times of flood; but as a matter of fact, it is believed that they often do take in water at these times, although no records are kept either of the times when water is taken in, or of the times when the sewage is discharged without treatment. This is one of the cases which one so often finds in England and elsewhere, where it is regarded as safer to have no information than to keep records. It should be said, however, that no evidence has been found that the health of the inhabitants of London is in any way affected by this discharge of sewage into the water courses from which their water is drawn; but this favorable condition is believed to be largely due to the great care with which all of the water is filtered.

The cases of the other class where sewage is purified to prevent its becoming a nuisance, but without regard to possible pollutions of water supplies, are very numerous. Many years ago England took the lead in works of this nature, and has at the present time probably a larger number of works than are to be found in all the rest of the world.

England has a very dense population, but it is far from being equally distributed over its entire area Near the southeast corner, on the tidal estuary of the Thames, is that enormous aggregate of population known as "Greater London;" and in central England, directly back of England's greatest harbor, Liverpool, is a small area which has become perhaps the most densely populated of any region of its size on the face of the earth, due to the harbor and to the deposits of coal and iron ore which there occur. Within a distance of forty miles from Manchester are Liverpool, Salford, Bolton, Preston, Oldham, Blackburn, Huddersfield, Birkenhead, Leeds and Sheffield, all of them great cities, and a hundred smaller places which so completely fill the intervening spaces that parts of the region have almost the aspect of one great extended city. A large part of the area is a broken hilly country, with steep, although not high hillsides, between which are narrow valleys in which are the railroads, mines and factories. The rivers, as they are called, are but short streams rising in the hills immediately back of the

cities, and many of them would hardly be dignified with the name of river in this country.

With the great development of manufacturing, the sewage and wastes were at first discharged directly into the streams until they became excessively foul, and the sewage problem was forced upon them in perhaps its most difficult form. There were but limited areas of land in the valleys with elevations which would allow their use for sewage purification, and even these areas were often occupied by mills, or held at high prices in expectation of such use, and the land itself was, as a rule, compact, impervious and but poorly adapted to sewage purification. The conditions in this region were probably more favorable for chemical precipitation, as against land treatment, than at almost any other place, and chemical precipitation has been the most commonly used method of treatment. Leeds, Sheffield, Bradford, Manchester, Salford and Huddersfield among the larger places using it. Chemical precipitation, however, although great improvements have been made in the form of settling tanks and in the methods of managing them, removes scarcely more than one-half of the organic matters in the sewage and never more than two-thirds, and the effluents generally carry on an average from two to five parts per hundred thousand of suspended matters capable of forming deposits in the streams; and it has been found that effluents purified to only this extent are very apt to produce more or less trouble when discharged into such small streams as exist in this region, and it is becoming more and more apparent that some more thorough process will be required before the problem can fairly be considered solved.

Already much has been done in this direction. At Sheffield the effluent is taken through coke filters at a very high rate, and a portion of the suspended matters in the effluent is thus removed, although the purification obtained is far from what might be desired. This use of coke for filtering material has this strong point in its favor, that when the coke becomes dirty it can be burned with the matters accumulated in it under the boilers that are sure to be in use at the works. At Huddersfield, the effluent is filtered through sand and a patented substance called "polarite," with the result that most of the suspended matters are removed, although the dissolved organic matters hardly have time to become oxidized with the rapid filtration employed.

At Bradford and at Salford experiments have been made on a considerable scale with rapid filtration through sand or coke, and forced aeration has also been experimented with in the endeavor to find a process which is at once very rapid and capable of yielding effluents comparable in purity to those obtained from land treatments. This question of further purification for chemical precipitation effluents is now being everywhere discussed, and experimental filters are to be found with a

surprising frequency, and we may confidently expect that the coming years will witness great changes in the methods of sewage treatment in this locality.

A little to the south of the Manchester district is Birmingham, a great manufacturing city, which treats its sewage first by chemical precipitation, and afterwards applies the effluent to a large area of meadow land on both sides of the small river into which it eventually finds its way. Leicester, a few miles to the east, uses substantially the same process.

At London the sewers from a large metropolitan district have been gradually combined into one great system, or rather two systems, one for the north and one for the south side of the River Thames, both of which are administered by the London County Council. The conditions here are in many respects different from those of almost any other large city. The sewage is carried down by intercepting sewers to points some miles below the city, and is discharged into the estuary where there are very powerful tidal currents in addition to the natural flow of fresh water from the river. Formerly the sewage was discharged without treatment at these points, but it caused so great a nuisance in the river, both to the shipping and to the residents upon the banks of the river, both below and above the points of discharge, that in the last years works have been built to treat the whole of it by chemical precipitation, except the storm overflows.

Although London is noted for its rainy weather, it seldom rains rapidly there, and the precipitation is more apt to come in the form of a slow drizzle, which the sewers are capable of removing, and the sewage which goes to the river through the overflows is much less than would be the case in an American climate. Mr. Santo Crimp, formerly in charge of the London Sewerage Works, has estimated that in the aggregate only about 4 per cent. of the sewage is discharged untreated into the river, the remaining 96 per cent. being treated before its discharge.

On Continental Europe the conditions for land treatment are, as a rule, more favorable than is the case in England, and chemical precipitation has gained but a slight foothold, only one large city, Frankfort-on-Main in Germany, employing it, although it is used at a considerable number of smaller places and is being considered at Leipsic.

In the early days of chemical precipitation lime was commonly employed as a precipitant, and where the sewage contains a large amount of iron and acid from wire works, as is the case at Leeds, Sheffield and Birmingham, lime answers as well or better than any other precipitant, but in other cases it has little to recommend it, and has usually been superseded either by copperas or by sulphate of alumina, although it is necessary to use with each of them a small quantity of

lime to insure rapid precipitation. At London copperas is employed, while other English cities have varied their precipitants from time to time.

One of the serious problems connected with chemical precipitation of sewage is the disposal of sludge, and in selecting the precipitant it is necessary to consider not only the purity of the effluent which can be obtained, but also the quantity and character of the sludge produced by it. At London several tank ships are employed which carry the sludge out to sea, each ship making two trips daily and carrying about 1,000 tons, of which 90 per cent. is moisture. To reduce the sludge to as small a volume as possible, it is pumped from the settling tanks into another set of smaller tanks and is settled over again, reducing it to one third of its original volume. From these the supernatant liquid flows back into the incoming sewage to be treated over again, and the remaining sludge is run into the tank ships. These ships are of steel and have air chambers in their bottoms to give them sufficient buoyancy so that the sludge will flow out through the openings in their bottoms when they reach the point of discharge, fifty miles from the works.

At Birmingham the sludge is run upon and dug into several hundred acres of land with fairly good results. At Sheffield and other places it is simply piled up on unused land and given away for a fertilizer when possible, and by sprinkling it with lime and with chloride of lime in summer, it does not become an unbearable nuisance, although this practice can hardly be recommended. Manchester and Salford have hoped to carry their sewage out to sea, as is done at London by means of the Manchester ship canal, but I do not know that they have yet commenced to do so.

Huddersfield and many of the newer works press the sludge in filter presses to solid cakes which can be easily handled and which can be applied to land or stored without creating a nuisance. The putrefaction, which makes sewage and sludge offensive, seems to require the presence of an excess of moisture, and when the moisture is absent, as in pressed sludge and in land used for sewage treatment, this putrefaction did not occur, but the changes which take place are of an inoffensive nature. The cost of pressing is considerable, and it is this which probably prevents it from being more generally adopted.

The shape of the settling tanks for chemical precipitation has been changed somewhat in the course of years. The earlier tanks were nearly square and were often used intermittingly; being filled with sewage, allowed to stand and afterwards emptied and then filled up again. This was known as the intermittent process and has been almost everywhere abandoned, although still in use at Sheffield. In the continuous process, now generally used, the tanks are connected with each

other and the treated sewage is run into a series of them, passing from one to another until finally it is discharged. The newer works, however, as a rule consist of long narrow tanks so arranged that a portion of the treated sewage passes through each of them and is then discharged, so that each tank is entirely independent of the others. These tanks are ordinarily from 30 to 60 feet wide, but are occasionally much wider, and in length range from one or two hundred to six and ten hundred feet. The bottoms slope rapidly from each side to the middle, and the middle slopes slightly from the outlet end of the tank toward the inlet, and there is usually a sludge channel in the middle a foot lower than the bottom, to insure a rapid removal of the sludge when the tanks are cleaned. All of the earlier tanks were open to the sky, but in 1884 Lindley built precipitation tanks at Frankfort covered with a vaulting with soil above, laid out as a garden. This arrangement prevents any possible interference with the sedimentation by the wind or by ice, and also makes a much more attractive appearing place than the open tanks.

The settling tanks at London are also vaulted. On the north side of the river the tanks are only 32 feet wide, and there is an arched spandrel wall half way between the sides, and the roof is made of two continuous arches covered with earth and with manholes to furnish light. It is stated that it was quite as cheap to build the tanks in this way as it would have been to build them open, because the walls between the tanks, being supported at the top, are very much thinner than would have been necessary with open tanks, and the excavated material was placed above the vaulting without expense for removing it, and the economies thus affected fully equaled the cost of the vaulting. The more recently constructed settling tanks on the south side of the river are of the same general construction, but the manholes were omitted, and it is found that there was both a great saving in the cost of construction, and the work of cleaning the tanks can be better done by artificial light throughout than by the very irregular light admitted through manholes.

Vertical settling tanks like those used at the World's Columbian Exposition at Chicago are occasionally used in Germany, particularly in small places, and are in some respects convenient, although the sedimentation is probably less complete than is the case with properly constructed horizontal tanks. The famous tanks at Dortmund are being replaced by broad irrigation.

In other parts of England, where the population is much less dense than in the districts mentioned and where land for sewage treatment is more easily secured, chemical precipitation works are the exception rather than the rule, and sewage farming is generally employed where sewage requires to be treated.

On the continent, Paris first adopted land treatment for sewage, many years ago, but selected an area quite near the city and which was only large enough to receive a portion of her sewage. The process was entirely satisfactory as far as purification was concerned. No nuisance was created, and some return was obtained from the crops on the capital invested. There was, however, no land suitable and convenient for treating the remainder of the sewage without going some miles further down the river, and for many years the system was not extended.

In the seventies, Berlin took the matter up and adopted substantially the same system which was then in use at Paris, and has since extended it from time to time until for many years all of the sewage of Berlin has been treated. Berlin with its immediate suburbs has, at the present time, a population of nearly two millions, and is growing almost as fast as Chicago, but the population is very compact, and the surrounding country for many miles consists of sandy land in every way suitable for sewage treatment, but too poor to repay ordinary cultivation. Under these circumstances, there has been no object in economizing in the area of land used, and the city has taken large areas of land and is extending the mains to irrigate as large an area, as possible with sewage. In 1893, 10,800 acres were in use receiving on an average 4,100 gallons per acre daily. The sewage is all pumped and treated, except when in thunder storms more rain falls than can be carried by the sewers. The Spree flowing through the heart of the city is said to have been as dirty as the Chicago River is at the present time before the works were commenced, but it has been so thoroughly cleansed that one would hardly suspect it of having once been polluted by sewage. The irrigated land is cultivated with some profit to the city, and in good years, 2 per cent. net profits on the capital of about $6,000,000 have been earned.

After Berlin adopted land treatment for her sewage, Dantzig and Breslau adopted substantially the same process, and more recently Magdeburg has been preparing land to be used in the same way, while Cologne, Hanover and other cities are talking of doing so.

The German cities, as a rule, are situated upon much larger rivers than are the English cities, and sewage disposal has not been so pressing a problem with them; but on the other hand the conditions for disposing of the sewage upon land are much more favorable than in England, and the expense of carrying out the process is less; and now that the process has been demonstrated by many years' trial in the three cities mentioned to be a practical success, the Imperial Board of Health, which has great power in these matters, is insisting upon the adoption of sewage purification in almost all cases where important extensions or changes in the sewerage systems are adopted. As everywhere else, it is

difficult to prevent a city which has been discharging its sewage into a river from continuing to do so, particularly where the river is large enough so that no great nuisance is caused. But when a city wishes to extend its sewerage system, or increase the size of its sewers, and the project is sent to Berlin for examination and approval, then the Board can take the position that the sewage should be purified, and it usually does so.

Some of the leading officials in Berlin having charge of the German rivers were of the opinion that all sewage should be treated without regard to the size of the rivers into which it is discharged, although a number of the rivers, such as the Rhine, the Elbe and the Oder, are so large that from our standpoint it is hardly possible to conceive of any appreciably injurious results from the discharge of sewage into them.

The soils used for sewage purification in Germany are invariably sandy, pervious materials, and the natural surface of the ground is so nearly level that it can be developed with a minimum of expense. The areas are usually divided into separate beds by low earth embankments, quite similar to those at Framingham and Marlborough in this State. The surface of these beds is always cultivated, grass, beets, cabbages, wheat, rye, oats and apple-trees being the leading crops. Wheat and oats when they are irrigated grow very rankly, and as the farmers say, run to straw, and good crops are seldom obtained. Our American corn or maize cannot be successfully grown, because the summers, and particularly the summer nights, are not warm enough, and the grain will not ripen.

Germany is some degrees farther north than New England and the winters are of about the same severity, but the winter nights are much longer and the days shorter, and it thus happens that in the darker months of the year it is impossible to distribute all, or even the greater part, of the sewage over the land by daylight, and it is found that however carefully instructions are given, the men having the distribution in charge will not properly perform their work at night. To provide for this contingency, certain areas are set apart upon all the German farms having substantially level surfaces and surrounded by embankments much higher than the ordinary embankments, that is 8 to 10 feet high. The areas are also much greater, often containing 10 or 20 acres in one lot. During the long dark nights of the fall and winter, sewage is run into these basins, often filling them several feet deep. Of course little purification takes place under these circumstances, but owing to the cold weather, the sewage is retained pretty nearly in its original condition, or at least without offensive decompositions, generally covered with an ice sheet during the winter.

As soon as the days become longer, in early spring, all of the

sewage is again applied to the land and these basins are no longer used. The ice melts and the pond of sewage soaks away in the course of a few weeks, and the surface of the land covered with the organic matters which have been strained from the sewage, is exposed to the air and becomes dry, and soon afterwards it is ploughed under, and the matters are destroyed, as in the ordinary process of intermittent filtration. Wheat and oats can be raised in these basins in the summer, and good crops are obtained. No sewage is ever put upon them except in winter.

Paris has for many years treated a portion of her sewage as mentioned above, by intermittent filtration upon the sandy soil of about 2,000 acres of land, nearly surrounded by one of the broad bends in the River Seine, just below the city. The sewage has been pumped to this land from the main outfall sewer as needed by the crops, and when the crops did not require it, the sewage has been discharged untreated into the river. In recent years, only about 20 per cent. of the sewage has been treated ; in rainy weather and winter a much smaller proportion, while at dry seasons a larger quantity was taken.

The condition of the River Seine, below the point of discharge of the sewage, has become extremely foul, and the city has recently voted to construct an outfall sewer down to another and larger area of land in the next bend of the river below that now used, and to treat the rest of its sewage there. This outfall sewer involves the construction of three siphons under the Seine, and the purchase of 25,000 acres of land, which will give the city an ample area upon which to purify all of its sewage. The estimated cost of this work is $6,000,000.

At Paris, as in the English sewage farms, the embankments between the beds are a much less conspicuous feature, and one of the most common methods of applying sewage is to have the land in ridges and furrows, the sewage being turned into the furrows, while vegetables and other crops are raised upon the ridges which are never covered by the sewage. Of course it is necessary at certain points to have embankments to prevent the sewage from running over the surface into the river, but these are reduced to a minimum.

There are some unusually interesting sewage disposal problems in some of the Dutch cities. Rotterdam is situated upon the Maas, which is really the main outlet of the River Rhine, with its enormous flow from the mountains in the south of Germany and in France and Switzerland, and in addition there are strong tidal currents, so that the city has no difficulty in disposing of its sewage. Amsterdam and The Hague, however, are not situated upon rivers, but only upon the intricate system of canals which intersects a large part of Holland. Streets, as a rule, are three or four feet higher than the water in the canals, and the houses are built upon foundations about even with the streets, and there

are no cellars. There is often a canal between every two streets, and in the few cases where it is omitted, it is in any case but a short distance from any part of the city to some canal. It has been the custom ever since the memory of man to discharge all sewage, garbage and other wastes into the canals direct. This has resulted in the canals becoming extremely foul and sources of much complaint.

The conditions have been somewhat improved by constructing considerable reservoirs, which, regulated by means of gates and used in connection with the tides, allow considerable currents to be maintained in most of the canals, and in this way the conditions have been maintained without becoming excessively bad. The limits of this system of flushing have, however, been nearly reached, and it is apparent that some further treatment will be required. Several of the leading Dutch engineers are exerting their ingenuity to see how a series of sewers can be constructed for The Hague, but the problems of ground water, canal crossings and pumping stations are really very serious.

In Amsterdam a portion of the central part of the city has been for some years sewered on the Liernur system. This system, which many of you will remember, was much talked about some years ago, and was thought by many to afford a solution of the sewerage problem. It consists of a system of iron pipes in which a partial vacuum is maintained, and into which sewage matters are passed without water, and the material is drawn in a concentrated form to a pumping station, where it is distilled with lime, giving off ammonia, which is condensed in acid to form an ammonium salt which is sold, and the residue is dried and compressed into cakes, which have some value as a fertilizer.

At the present time about 62,000 people are connected with this system in Amsterdam, and about six tons of ammonium sulphate are produced per week, which partially pays for the cost of operation. The system is being slowly extended to other parts of the city, although perhaps it is too soon to state that it is the definitely adopted plan of the city, and developments may be awaited. This is altogether the largest plant upon the Liernur system, and possesses very great interest to those only familiar with the water-carried system of sewerage.

The question as to the dilution which it is necessary to give a sewage or a sewage effluent in order to prevent the creation of a nuisance, is a most interesting one. Unfortunately, statistics as to the flow of streams at the points where they pass various cities are extremely difficult to obtain, and even in those cases where statements are available there is often a question as to the exact conditions under which the gaugings were obtained, and as to whether the results are comparable with corresponding statements for other places.

The flow of rivers, however, is in a measure proportional to the

areas of the watersheds from which they flow, and these watersheds can be measured with ease and with comparative accuracy. The flow, and particularly the minimum flow, in which we are especially interested, of course depends upon the rainfall, and its distribution throughout the different seasons of the year, as well as upon the climate and the geological character of the watershed. But after making due allowance for differences of this nature, the comparative figures for the areas of watersheds are more satisfactory than any records of gaugings which could be obtained for all the numerous points in which we are interested.

In the following table are given the names of a number of cities having interesting sewage disposal problems, and their populations, as given in the last census for 1890 or 1891, as the case may be, together with the rivers on which they are situated, and their drainage areas measured from the points at which sewage is discharged into them, and in the last column the areas of the drainage areas per thousand of population. The areas, with one or two exceptions, have been measured from maps and are only approximations.

City.	River.	Population.	Drainage Area.	Square Miles per 1,000 of Population.
Manchester	Irwell.	198,136	290	0.41
Salford		505,343		
Brussels	Senne.	477,000	340	0.72
Leeds	Aire.	367,506	310	0.84
Sheffield	Don.	324,243	320	0.99
Bradford	Aire.	216,361	220	1.02
Huddersfield		95,422	102	1.06
Chemnitz		138,955	160	1.15
London	Thames.	4,211,056	4,900	1.16
Glasgow	Clyde.	658,198	800	1.22
Berlin	Spree.	1,578,685	3,800	2.40
Munich	Isar.	348,000	1,200	3.45
Leipsic	Elster.	355,485	1,700	4.80
Brunswick	Ilse.	100,883	600	6.00
Paris	Seine.	2,417,957	16,000	6.50
Hanover	Leine.	163,100	2,000	12.30
Breslau	Oder.	335,174	8,500	25.50
Frankfort-on-Main	Main.	179,850	9,500	53.00

Manchester and Salford, on the opposite sides of the Irwell, discharge their sewage into it at nearly the same point, after treating it by chemical precipitation.

The population given for Brussels includes suburbs more populous in the aggregate than the city itself, and it is probable that only a part of them are connected with the sewers. The sewage is not treated and

the river is extremely foul below the city. The river has been straightened and arched over through the central part of the city, and a boulevard has been built over it, and intercepting sewers on either side of it are carried down to a point below the city, at which the sewage is discharged.

At Leeds the sewage is treated by chemical precipitation before being discharged into the Aire, and at Bradford also, the sewage is precipitated and discharged into a brook just above its junction with the Aire, but the drainage area given is that of the Aire below the junction of the brook.

Sheffield and Huddersfield treat their sewage by chemical precipitation and follow the treatment with rapid filtration.

The rivers mentioned above have been among the most grossly polluted rivers in Europe, and notwithstanding the efforts that have been made to purify the sewage, they are in far from satisfactory condition, although it seems probable that the large amount of cloudy weather, and absence of extremely hot weather in England in summer, at once have a tendency to maintain larger minimum flows, and are less favorable to the offensive decompositions that would be expected in a hotter climate and drier atmosphere.

Chemnitz discharges its sewage without treatment into the small stream which flows through it, and a serious nuisance is created which will probably be corrected in the near future. The stream has quite a rapid fall, and it is perhaps this fact which has made the discharge of so much sewage possible.

At London and Glasgow, the sewage is discharged into estuaries, where there are powerful tidal currents, in addition to the flows of fresh water, which render comparison of them with inland cities impossible. At London, the sewage is treated by chemical precipitation, and a similar treatment, followed by rapid filtration, has recently been put in operation to treat a portion of the sewage of Glasgow.

At Berlin, the condition of the Spree became very offensive in the early seventies, when the population was only half as great as at present, and the drainage area per thousand of population was consequently twice as great. Since that time, the sewage has been treated by broad irrigation, and the river is now in good condition.

At Munich, the sewage is discharged untreated into the river Isar, and has caused no serious nuisance. The river, however, has its origin in the Alps, and has a large flow and a rapid fall, so that the conditions for the discharge of crude sewage are unusually favorable.

At Leipsic, the untreated sewage has created a serious nuisance, and will be treated at an early date. Brunswick and Hanover do not treat their sewage, but probably will apply it to the land in the near future.

At Paris, the Seine has become extremely foul, notwithstanding its large drainage area and the fact that part of the sewage has been treated. Deepening the river to allow the passage of ships of considerable draft has reduced the velocity of the current, and made the conditions more favorable for the formation of deposits of sewage matter, with the decompositions which accompany them.

At Breslau, the sewage has been treated for many years by applying it to land, and the river has, so far as I know, never been in bad condition. Water taken from the river is used for public water supply by at least two large cities down the river.

At Frankfort-on-Main the sewage is treated by chemical precipitation before being discharged into the artificial harbor which has been constructed by building a dam at a little distance below, and by deepening the channel opposite the city.

While the data given in the table are perhaps hardly adequate to serve as a basis for final conclusions, they are interesting as showing the discharge of crude sewage without nuisance into a rapid mountain stream, having only 3.5 square miles of drainage area per thousand of population, while the discharge of sewage into smaller streams proportionally, has always resulted in the production of a nuisance, and other streams drawing their water from flat prairie country and with sluggish flows, have become offensively polluted, although their drainage areas were equal to 6 or 8 square miles per thousand of population, and one can readily see that in a region like the western part of the Mississippi basin, where rivers go nearly or entirely dry in summer, sewage might cause a nuisance even though the watershed was enormously greater proportionally than the above figures. We also see that cities have grown up upon rivers so small as to furnish less than half a mile of drainage area per thousand of population, and while in these cases, by giving the greatest attention to the thoroughness of the purification of the sewage before discharging it, rivers can be kept in fairly good condition, the problem is a difficult one and requires the utmost and continued care to keep the streams even in reasonably good condition.

In conclusion, the trend of the best European practice in sewage disposal is strongly toward the treatment or purification of sewage in all cases before it is discharged into rivers, with the exception of very large rivers, and at points where there are strong tidal currents. The tendency is to use land treatment wherever the local conditions are reasonably favorable, as the effluents produced in this way are of much greater purity than can be obtained by any chemical or mechanical processes, and the cost is ordinarily less. Where the local conditions are such as to preclude the employment of land treatment, chemical precipitation is

used, but although material improvements have been introduced in the construction of settling tanks and in the methods of applying chemicals, it is not possible to produce effluents of sufficient purity to be discharged into the smaller rivers without creating more or less complaint, and the tendency is strongly to follow chemical precipitation in such cases by a rapid filtration through some material which will remove substantially all of the remaining suspended matters, and will allow at least a portion of the soluble organic matters to become oxidized.

MECHANICAL ANALYSES OF SAMPLES OF MATERIALS FROM CERTAIN EUROPEAN AND AMERICAN SEWAGE FARMS.

COLLECTED BY THE AUTHOR.

(For methods of analyses see Report of Massachusetts State Board of Health for 1892, page 541.)

Location.	Description of Samples.	Effective Size, 10 per cent. finer than: (Millimeters).	Uniformity Coefficient.	Albuminoid Ammonia, Parts in 100,000 by weight.
Berlin, Malchow Farm.	Surface soil where it had recently been ploughed.	0.12	5.6	34.
" "	Subsoil two feet deep at same place.	0.12	3.4	33.
" "	Surface soil not recently ploughed.	0.12	2.2	90.
" "	Subsoil two feet deep at same place.	0.13	2.7	31.
Berlin, Grossbeeren Farm.	Surface soil in actual use.	0.15	2.0	26.
" "	From a sand bank near by representing the original unused material.	0.15	1.8	1.
Breslau.	Subsoil one foot below surface of sewage field in use.	0.24	1.9	2.
Paris.	Surface soil from sewage fields in use.	0.13	5.9	64.
Framingham, Mass.	Sand from sewage filters.	0.35 to 0.42	4. to 5.	
Marlborough, Mass.	" " "	0.12	3. to 4.	
Gardner, Mass.	" " "	0.10 to 0.24	6. to 14.	
Brockton, Mass.	" " "	0.30 to 0.60	2. to 5.	
Poughkeepsie, N. Y.	Sand from sewage filters at Vassar College.	0.10 to 0.50	2. to 5.	0. to 2.
Plainfield, N. J.	Sand from sewage filters.	0.10 to 0.25	2. to 5.	0 to 3.
Pullman, Ill.	Soil from sewage farm.	0.01	15.	225.

SOLID FLOOR BRIDGES FOR RAILROADS AND HIGHWAYS.

By Frank C. Osborn, Member of the Civil Engineers' Club of Cleveland.

[Read before the Club, November 12, 1895.*]

The term "Solid Floor," as applied to railroad bridges, is here used to distinguish the various types of continuous metal floors, as made up of plates and angles and other special shapes, from the ordinary open floor of timber cross-ties laid on longitudinal stringers or joists of wood or iron.

A highway bridge floor must necessarily be continuous and, in that sense, solid; but this paper refers to such types as might perhaps be better called "permanent" floors to distinguish the various forms of floors adapted to the use of brick, stone block, asphalt or macadam paving, as opposed to the more common floor of one or two thicknesses of plank laid on wood or iron joists.

The use of solid floors for railroad bridges has increased largely in the past few years, and has been brought about by various considerations, among which may be mentioned the following:—

(1) The elevation of tracks in the larger cities requires as shallow floors as possible, in order to give suitable clearance over streets, and this can best be accomplished by the use of all-metal floors. A closed floor is also necessary to prevent the falling into the street of coals, ashes, etc., from passing trains. It is also desirable as affording better protection in case of derailment.

(2) The solid floor is also used to give, as near as practicable, the same rigidity and permanency as the ballasted road-bed and a perfect support to trains, whether on or off the track.

The first solid-floor bridges for railway or highway purposes were doubtless those of masonry arches, and it would appear that, with the exception of a few of the earliest and crudest of the bridges of history, bridges with solid floors were the first used, and that the lighter, open and less expensive floors now so common, particularly in this country, are of more recent origin.

Following through the early history of bridge construction, masonry arches of various forms, cast-iron arches, etc., the first bridge built with a solid floor as we now understand the term, seems to have been the famous Britannia tubular bridge, built in 1845, Robert Stephenson,

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engineer. The total length of this structure is 1511 feet, and the weight 9360 tons. It cost £601,865, or £64.3 per ton, equivalent to about 14 cents per pound. Drawings of this bridge are not easily attainable, but the sketch (Plate I, Fig. 1), gives a good idea of the arrangement of the floor. It consists of built stringers covered top and bottom by plates, the upper plates supporting the rails on wooden longitudinal sleepers and rail chairs. This solid floor was, however, incidental, as its first duty was to act as a bottom chord. The Britannia Bridge is still in service; a monument of the first bold departure from the then existing methods of bridge construction.

From that time to within the past twenty years it is difficult to find many specific examples to show the progress in solid metallic floors. There seems to have been but little interest taken in their design, and, though the English even at that time used solid floors almost exclusively, there seems to have been but little variety in the forms and devices used. Cast-iron decking plates of various forms were used for many years. Mr. Mallet's invention of buckled plates, somewhere about 1861, marks an interesting advance, and seems to be the first special form of wrought iron devised for flooring purposes. Prof. Rankine mentions this in his Civil Engineering.

The Severn Bridge, of the Severn & Wye and Severn Bridge Railway, was commenced in 1875 and opened in 1879. The following is a description of the floor: "The top and bottom chords of the span are connected by vertical members which carry the cross girders. Small longitudinal girders between the cross girders support the rails, and the floor is made of plate iron decking."

The New Tay Bridge was built between 1881 and 1887, to replace the older bridge, which had failed in December, 1879. The plans for this bridge were approved in 1881, and included a trough floor of the form shown (Plate I, Fig. 2). Cross girders were used over the piers, but elsewhere they were dispensed with. The floor troughs rest on the bottom flanges of the girders and are riveted by means of angles to a continuous web forming part of the bottom chord. The troughs are filled with ash and cinder ballast, and the cross-ties are laid therein, spaced rather closely together.

This appears to have been the first form of trough floor designed, and following it a large number of different forms were devised, some of them patented, and used on various bridges. Conspicuous among these is Lindsey's floor (Plate I, Fig. 3), a form which has found great favor both in Europe and America, and one still frequently used. The drawing shows a floor for a short plate girder bridge, using the "C Max." troughs laid transversely and intended to be used with rail resting on a longitudinal sleeper bolted to the tops of the troughs. This section has

a moment of resistance of 198.9 inch tons, and weighs 32.97 pounds per square foot of floor. The largest form rolled is shown in the small sketch. This form has a moment of resistance of 1325.15 inch tons, and weighs 56.76 pounds per square foot.

In 1887 Mr. Edmund Olander read an exceedingly interesting paper before the Society of Engineers, entitled "Bridge Floors, Their Design, Strength and Cost." In this paper Mr. Olander discussed all the principal forms that had appeared up to that time, reducing them to a common depth and weight per square foot of actual area covered, and determining their comparative strengths and costs. Some of the more interesting forms are shown on Plate I, Fig. 5. Of these, No. 1 was an ideal section introduced by Mr. Olander for comparison. No. 4 is a form made by Messrs. Braithwaite & Kirk, patentees, West Bromwitch, and used, some two years ago, by Mr. Copperthwaite, M. I. C. E., on the southern section of the North Eastern Railway, for a bridge of 64 feet span. A form similar to No. 4 was used on the Tower Bridge, London, the principal difference from the form illustrated being the elimination of the joint and line of rivets at the bottom of trough, making a complete trough of each piece and jointed with one line of rivets at the upper part only. No. 5 is Baillie's patent floor. No. 6 will be recognized as the general shape of trough floor so much in use in America during the past five or six years, and it is interesting to note that for the dimensions used by Mr. Olander for comparison with the other forms, he finds this to rank lowest in his list of ten sections discussed, it having the largest number of rivets and the lowest moment of resistance. One other form discussed by Mr. Olander is the Lindsey floor, described above; the others of the ten are uninteresting in comparison with these, and have been but little used.

Later, Hobson's Patent Floor appeared (Plate I, Fig. 6), composed of several forms of bent plates connected by tees and made water-tight by a filling of asphalt in the V-shaped channels. The sketch shows the floor as adopted for the Liverpool Overhead Railway, six miles in length, and built within the past three or four years. Messrs. Greathead and Fox, in a paper before the Inst. C. E. (Vol. CXVII, pp. 51–70), gives the following description of the flooring:

"Between the girders (the main girders of the viaduct), is fixed Hobson arched-plate flooring, consisting of $\frac{5}{16}$-inch plates, bent to a radius of 12 inches, with a flat surface 6 inches wide on the top, riveted to intervening tee bars, and made water-tight by asphalt placed in the vee-channels between the arches. Upon this are laid longitudinal creosoted sleepers keyed to the flooring, and no ballast is used. From each vee-channel an outlet for water is provided through the web of one of the main girders, discharging into a light cast-iron gutter carried

along the outside of the main girder, which conveys the water to a rectangular down pipe fixed to the columns and delivering into the drains or gutters below. This flooring combines great strength with lightness and minimum of riveting, while the load is more evenly distributed along the main girders than is the case where cross girders are employed, and great lateral stiffness is secured without horizontal bracing. The flooring is practically water-tight, and after twelve months' test under traffic has not shown any defects. In order to ascertain the strength of the floor, some sections were tested to destruction, and the deflections at each increase of load carefully tabulated with the following results:

"TEST:—Three sections of floor measuring 7 feet 6 inches in width; span 22 feet, ends resting upon supports; load distributed over four points corresponding with the positions of the rails.

Load, Tons.	Deflection at Center.
30	Nil
35	$\frac{1}{4}$ inch
40	$\frac{7}{16}$ "
50	$\frac{9}{16}$ "
60	$\frac{3}{4}$ "
70	$\frac{15}{16}$ "
80	$1\frac{1}{8}$ "
90	$1\frac{1}{4}$ "
100	$1\frac{9}{16}$ "
110	2 inches

"The floor-plates ultimately collapsed by a total rupture of the tee-bars at 163 tons, and with a deflection of 10 inches.

"In the preliminary stages of manufacture of the floor considerable difficulty was experienced. The plates were heated in a furnace and were bent in a hydraulic press by dies to the required form, but it was found that in cooling the extreme ends curled upwards and spread outwards. After many trials, and by giving the dies a "set" in opposite directions, and by fixing the plates in a simply constructed frame to cool, truth and uniformity in the shape of the plates was eventually secured. The rivet holes along both edges of the plates were then drilled simultaneously by special machinery. The system was brought to such perfection, that from a single heating oven and press, and from one drilling machine, occasionally 45 plates, or sufficient to floor the viaduct for a length of 112 feet, were turned out daily, bent, drilled and ready for fixing. At the final operation, 344 plates were pressed in six days by one gang of men. When they were ready, bent and drilled, a tee-bar was riveted between them at their springing. The rivets were closed up by means of machine riveters, both heads being easily accessible from the under side. The rivets were put in by each machine at the rate of 400 per hour."

The following description of the solid floor on the Forth Bridge, begun 1882, completed 1890, is taken from *Engineering News:*

"The bridge carries a double track railway, and each line of rails is laid in a trough built up of plates and angles forming a guard on each side of each rail (Plate I, Fig. 8). The tracks were laid with rails of bridge section, weighing 120 pounds per yard, and about 28 feet long. They are secured to teak longitudinals by screw spikes 8 inches long, which pass through the flanges of the rail. The longitudinals are about 12 inches by 6 inches in section, and are kept in line by horizontal wedges driven between them and the sides of the troughs, which prevent the use of transverse connections. At joints and some other places a filling of vertical creosoted pine blocks is used, making a good-looking piece of work, and being very safe in case of derailment. It is not to be put in continuously, however, partly on account of the cost, and partly as it would prevent inspection of parts of the iron work of the trough. The timbers rest upon a continuous bearing of wooden blocks with pitch filling. The floor is of buckle plates with holes to let off the water. There is no ballast. The floor seems to be very rigid and without sufficient provision for cushioning the vibrations started by trains. The trains make a harsh metallic sound and a jarring in passing over the bridge, and this noise and uneasy jarring are unpleasantly noticeable in riding in the cars. The change is very pronounced when the train runs into the embankment approach, where the track is laid with the same rails on longitudinals, with transoms, in broken stone ballast; the train then riding smoothly and quietly."

All, or nearly all, of the English railways use solid floors extensively on their bridges. The Great Western Railway uses troughs laid transversely and filled with ballast. Trough floors are also used on the Great Eastern Railway, notably on that part not far from the Liverpool Street terminus where the track is elevated on brick viaducts with plate girder bridges across the streets.

The great bridge over the Mersey at Runcorn has an iron floor, with angle iron guard rails on each side of and at some distance from the track rails, forming a wide trough.

When, between 1886 and 1890, the London & Southwestern Railway widened its line to accommodate two more lines of track, and replaced its oldest cast-iron bridges with girders, a trough floor was used on the bridges of the form described in connection with the Tower Bridge, London, resting on the bottom flanges of the girders. The troughs were made eight inches deep, of ½-inch metal, which received two coats of Stockholm tar after they were placed in position, and then filled with a mixture of tar and gravel.

The rails are supported on longitudinal timbers, 18 inches by 7

inches, secured to the floor troughs by angles. To carry off the surface drainage, there is a 1-inch hole in each trough, close to the connection with the central girder, this girder being set $1\frac{1}{2}$ inches low, and a wrought-iron girder is riveted to the soffit of the flooring, and carried to the abutments, whence the water is conveyed to the street sewer by a down pipe built in a chase.

These works are very completely described, and results of tests of the flooring given in a paper by Mr. Alfred Weeks Szlumper, before the Inst. C. E. (see Vol. CVII, pp. 287–304).

The writer has lately had called to his attention a new English floor known as Knight's Improved Steel Floor Plate. This form was patented October 16, 1894, and is intended for use on all kinds of bridges as well as for warehouse floors, etc. The drawing (Plate I, Fig. 7) shows its method of application longitudinally for a railroad girder bridge, but it can be placed in any position, with troughs running longitudinally or transversely, and either side up. The inventor claims the combined advantages of both trough and buckle plate forms.

The Swiss Northeastern Railway has in use several bridges with solid trough floors. The type is shown by the drawing (Plate I, Fig. 4). The troughs are used both transversely and longitudinally, the form of trough being decidedly different from others. One distinguishing feature of these bridges is the method of carrying the ballast uninterruptedly from bank to bank. This mode of construction is found to make the structures from 10 per cent. to 15 per cent. heavier and more expensive, but on the other hand their vibrations are reduced almost to a minimum. The troughs rest on flat straps of iron $\frac{5}{32}$ inch high and about 2 inches wide, fastened to the tops of the floor beams by countersunk rivets. These straps serve to protect the angles of the floor beams from being bent downward from strains on the troughs, and also to transmit the live loads to the floor beams axially. On both sides of the track, sheets of iron are placed, resting against the gusset plates connecting the floor beams with the main girders. The box thus formed receives the ballasting to the height of 12 inches above the tops of the troughs. The ballast rests upon a solid layer of concrete, which covers the troughs entirely. A very strong and heavy cross-section of trough is used, the width of foot being 12 inches, height 5 inches, weight per yard 62.5 pounds, material, mild steel.

A peculiar solid floor on a single track railway bridge in Germany is described in the *Centralblatt der Bauerwaltung* by Reinhard Goering. The transverse girders are connected by five stringers which are covered by trough plates filled with concrete. The concrete is covered in turn by asphalt, forming a firm bed for a course of corrugated galvanized iron. The corrugations are 6 inches wide and 18 inches

deep, running across the bridge. On this is gravel ballast confined at the sides by metal plates, forming an inclined curb. The drainage water percolates through the gravel to the corrugated iron, and thence by longitudinal sheet-zinc troughs to the earth back of the abutments. The total cost of the floor is said to be 95 cents per square foot.

Solid floors are used extensively in India, many forms being in use. Some of the older brick arches were repaired by making a solid floor of old rails laid lengthwise and covered by at least 9 inches of ballast. Some buckle-plate and trough-shapes are used, and Messrs. Dorman, Long & Co., Limited, of Middlesborough, England, illustrate a special shape of troughing in their hand-book of steel sections for use on the Indian State Railways. It is very like the form used on the Tower Bridge in London, and described above.

In America, solid floors for railroad bridges were not introduced extensively until within a comparatively recent period. It is true, a few bridges were built with floors which would be properly considered in this history, although not included precisely within the term as generally used in connection with railroad bridges, since they were used not so much for the reasons now so seriously considered as to obtain a bridge floor safe against fire, or, on short spans, to cheapen the cost of the floor by omitting the common form of floor-beams and stringers.

As early as 1874, small bridges were built with a floor of old rails laid crosswise directly upon the top chords of the girders or trusses, and covered with ballast in which were bedded the ties. Several such bridges still exist and give satisfaction. A number of rail floors were laid on the New York Central about 1874 and later, consisting of old rails laid lengthwise, directly upon the abutments of short spans, and close together for 12 feet in width. Upon these were placed one foot of gravel ballast and the track laid directly thereon.

There is a peculiar metal floor on the N. Y. & N. E. R. R. bridge over the N. Y. C. & H. R. R. R. tracks, at Fishkill, N. Y., which, while it cannot be properly classed as a solid floor, is interesting in connection with rail floors. It consists of built floor-beams and stringers of usual construction, but instead of using wooden ties, old rails, planed on the ball, are placed across the stringers upside down, and held in position by bent plates riveted to the top flanges of the stringers and bolted to the webs of the rails. Upon these the track and guard rails (the latter also of railroad rails) are laid and fastened, and lines of $\frac{5}{16}$-inch deck plates are laid between the track and guard rails and for a width of 14 inches inside of the track rails on each side.

For a number of years, also, wooden trestles have been in use on some of our railroads, with solid wooden floors covered with ballast.

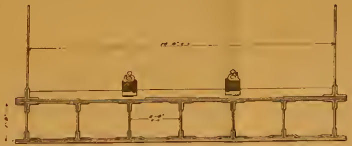


Fig. 1.
Britannia Bridge.

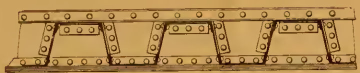
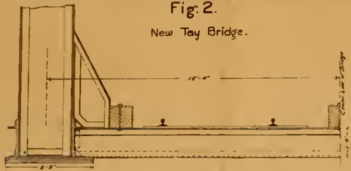


Fig. 2.
New Tay Bridge.



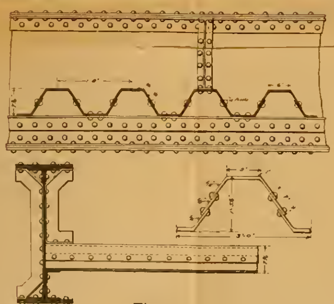


Fig. 3.
Lindsey's Floor.

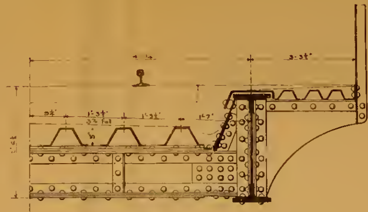


Fig. 4.
Swiss Northeastern Ry

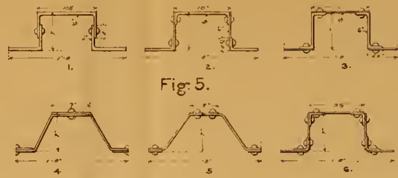


Fig. 5.

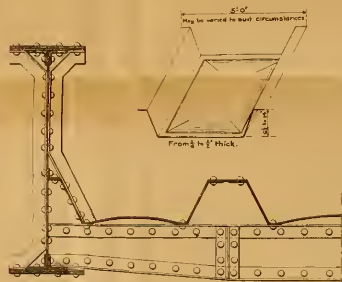


Fig. 7.
Knights Patent Floor

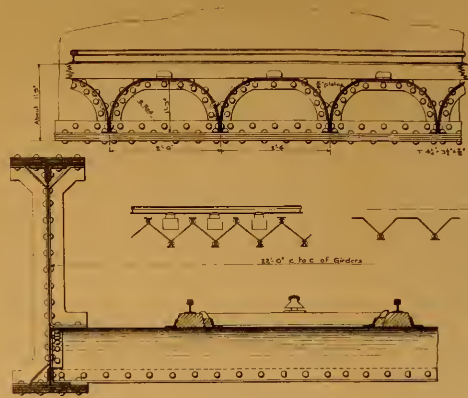


Fig. 6.
Hobson's Flooring.

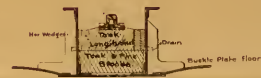


Fig. 8.
Forth Bridge.

Solid Floor Bridges for Highways & Railroads.

PLATE 1.

European Bridge Floors.

to accompany paper by Frank C. Osborn

For illustration, the type of wooden trestle used in many places on the Southern Pacific Railway is shown on Plate III, Fig. 7. This type of floor has been used on this road since 1887. Mr. Julius Kruttschnitt, to whom the writer is indebted for plan and description of the floor, says:

"These ballasted structures are built of creosoted timber only, which we treat at our own wood-preserving works near Houston. Their cost, for heights varying from 4 to 12 feet, is from $8.00 to $8.50 per lineal foot, built under traffic, the lower cost applying to trestles of four or more panels, and the higher to trestles of less than four panels.

"We have never experienced the least want of better drainage, or any lack of stiffness, as you can well imagine from the substantial character of the floor.

"Perhaps the best manner in which to illustrate our faith in this style of floor, would be to state that on January 1, 1895, we had some 45,730 lineal feet of these structures in our main line of 1200 miles, and from the time of their inception to the present time, we have spent nothing on them for ordinary repairs.

"The durability of these structures depends, in the main, upon the life of the creosoted timber used in their construction, and whilst this life is not within the range of our own experience, we are led to believe from the experience of others that we can conservatively count on twenty years, at least."

Several other railroads have wooden trestles with solid ballasted floors. The Houston and Texas Central Railroad has a standard type of trestle differing somewhat from that of the Southern Pacific. Eight lines of 7 x 14 inch stringers are placed on the caps of the bents, and are covered with 2 x 12 inch planking 14 feet long, laid crosswise. 4 x 6 inch longitudinal pieces are bolted to the ends of the planking to catch the ballast. The track is laid in the ballast in the ordinary manner. This type is also built of creosoted timber, and the average cost is $8.50 per lineal foot.

The Illinois Central Railroad has also used solid floor trestles on some of its southern divisions, built of black and red cypress without creosoting. Their life is estimated at twelve years. The general design of the floor is very much like that of the Southern Pacific type.

Mr. Wolcott C. Foster, in his book on "Wooden Trestle Bridges," illustrates a solid floor pile trestle, with ballasted road-bed, used on the Louisville and Nashville Railroad. The Richmond, Fredericksburg and Potomac Railroad also uses a ballasted wooden floor on trestles as a protection against fire and to deaden the noise. Mr. E. T. D. Myers, in writing of this floor, says: "Our experience goes to show that the supporting wooden stringers are quite as durable, if not more so, under such treatment."

A noticeable point in all these wooden floors is the absence of guard rail of any kind, the track being laid and maintained in the ballast precisely the same as upon other parts of the road.

Some time in 1887, Mr. George S. Morison prepared plans for his bridge across the Willamette River. The conditions surrounding its construction were such that a very stiff and permanent floor must be designed with very scant depth. Mr. Morison went across the water for his idea, and adopted the Lindsey trough for the floor of this bridge, using a section about 12 inches deep. This, so far as the writer is able to determine, is the first instance of a solid metal trough floor used in America. Later, in designing a bridge in Omaha, Mr. Morison had occasion to use a solid floor in order that the tracks might be laid upon it in any position and that a tight floor over the street might be obtained. He prepared patterns for a trough shape similar to that used upon his Willamette bridge, and the troughs were rolled by the Pencoyd Iron Works. This appears to have been the origin of the "Pencoyd Section" still so frequently used, and to account for the similarity between this section and the earlier design of Lindsey's floor in England.

Shortly after this, or in 1888, the New York Central began its work of building solid trough floors for bridges and covering them with ballast, thus obtaining a continuous ballasted track from bank to bank. This road is conceded to have been the first to adopt solid metal floors as a standard, and appears to have adopted this standard in compliance with a law enacted in the State of New York, on November 1, 1887, providing that floor systems shall be maintained on all bridges so constructed as to support a derailed locomotive or cars. The first of these to be built was bridge No. 547 on the Mohawk and Hudson Division, and the form of ballasted trough adopted for that case is essentially the same that has been most extensively used ever since on this road, consisting of plates and angles forming parallel square troughs, in which are placed the ties on ballast.

The drawings (Plate II, Figs. 1 and 2) show two types of floors used on their shorter spans. The first is Pencoyd's Section No. 209, weighing 24.8 pounds per square foot. This is said to be the cheaper form for small openings. The other form is their standard square trough. The drawing shows the floor on the four-track bridge over the 165th Street sewer. The total length is 24 feet, clear span 21 feet, and 2 feet depth of floor. The cost, including ballast, etc., was $500 per track, equivalent to about $21 per lineal foot of single track.

The Oriskany Bridge, on this road, was built in 1889 and carries a solid floor of the square trough pattern suspended by angle hangers from a stiff bottom chord. This, like most of the others, is ballasted. The floors of the longer spans are built with the troughs running transversely

instead of longitudinally, as shown on the drawings representing the shorter spans.

The New York Central is now finishing a large bridge and viaduct approach over the Harlem River, using the same square troughs, but in this case they expect to rest the rails directly upon the troughs, fastening them on rail-plates by means of a special clip. On the approach, also, the design has been slightly changed in detail to facilitate field riveting by increasing the width of the top horizontal plate at the field splices of the floor and turning the corresponding angle into the trough. This does away with so much field riveting through the floor.

In the summer of 1889, Mr. A. F. Robinson, then in the employ of Mr. E. L. Corthell, designed the solid floors for the Clyde crossing of the Chicago, Madison & Northern Railroad over the tracks of the Chicago, Burlington & Quincy Railroad, near Chicago. This was also a square trough, 12 inches deep, resting upon shelf angles riveted to the stiff bottom chord of the pin-connected truss, or to the web of the girders, just above the flange. By this design a total depth from base of rail to bottom of structure of only 18 inches was obtained. Shelf angles were riveted at intervals in the troughs 6 inches below the tops, and the 8-inch ties rested upon these angles, thus clearing the rail 2 inches above the iron work.

The New York, Providence & Boston Railroad began giving attention to metalic solid floors about 1889. Their bridge No. 69 at Saundersville, Mass., was built during the summer of that year. It consists of Pencoyd Section No. 209, 57.9 pounds per yard, filled with asphalt and ballast. Several other cases might be noted where one or the other of these two forms of trough, viz., the square trough of plates and angles and the Pencoyd Section, were used previous to 1890, but up to that date there seems to have been no other form applied.

But, that American engineers were rapidly waking up to the great advantage and many merits of solid metal floors for railroad bridges, is evident from the greatly increased space given to their consideration in the engineering papers from this time on, and by the following extract from President Wm. P. Shinn's annual address before the convention of the American Society of Civil Engineers in 1890:

"The subject of bridge floors is one which has long needed more careful attention, and it is gratifying to observe that the New York Central has awakened to its importance, and is now building or refitting many of the short-span bridges with solid buckle plate or plate-iron floors, upon which the ballast is carried uninterruptedly. Every experienced engineer of maintenance of way knows how extremely difficult it is to secure and maintain such perfection of surface that the transitions from ballast to track on wooden bridge floors and vice versa shall be

smooth and without shock. This difficulty is avoided by the character of floor adopted by the New York Central. Its advantage in case of derailment was shown on November 12, 1889, when five cars of the west-bound freight train left the rails and dragged across the new Erie Canal Bridge at Rome, which had been provided with a floor of this character. The cars were scattered all over, two having their trucks pulled from under them; the ties and road-bed were torn up so that it looked as if the company had been trying to run one train on two tracks, but no damage was done to the bridge. It is plain that true economy calls for construction of this character, where it is possible, or where, as is being done by the Pennsylvania Railroad Company, it is not found practicable to replace the iron bridges with stone arches."

From this time forward, other forms rapidly came into use, and new designs or modifications of older ones appeared in rapid succession as the details of construction for various needs and special cases were worked out by different minds.

Mr. Robinson read a paper before the American Society of Civil Engineers in September, 1892, presenting a design for a solid trough floor. His object was to obtain a shallow floor of the most acceptable pattern, and he adopted a square trough of plates and angles, differing only in detail from that which he used in the design of the Clyde Viaduct, already described. He uses a pin-connected span without the stiff bottom chord and connects his troughs by bent plate hangers to an auxiliary plate girder which is fastened to the posts below the lower chord pins. He uses wooden ties resting on bent plate shelf supports in the troughs. Mr. Robinson gives the following reasons for adopting the square trough of plates and angles:—

"*First.* For through bridges the box floor must be suspended (on account of scant head-room), which makes vertical webs necessary.

"*Second.* A floor is required in which the width and depth of the boxes can be easily varied.

"*Third.* In section No. 4 (see No. 2 of Fig. 5, Plate I), there are channel bars, the price of which is usually controlled by a pool. In section No. 5 (see No. 3 of Fig. 5, Plate I), there are Z-bars which are not, at present, rolled as deep as necessary for our floor."

Mr. Geo. H. Thomson, in discussing the above paper, presented drawings of several forms of metal floors used by him in various bridges. One of them is of interest here, being different from those thus far discussed. It consists of Pencoyd Section No. 260, connected by horizontal plates, the troughs thus formed are riveted to the top flanges of the main girders and the bottoms filled with asphalt concrete laid to drain to the center, the concrete covered with stone ballast six inches deep between tops of troughs and bottoms of the wooden ties. Mr. Thomson says of this form:—

"Some difficulty is experienced in making the troughs fit the girders, owing to the stretch of the former after manufacture."

The discussion of Mr. Robinson's paper also brought out the suggestion of a new form of trough which, though it has never been used, is worthy of mention. Mr. Barbour wrote to the *Engineering Record*, under date of September 29, 1892, suggesting a floor of channels and plates (Plate II, Fig. 10), claiming economy in such a form. In a later communication Mr. W. Bleddyn Powell says:—

"I would respectfully urge in place of such a section one composed of Z-bars, as the distribution of metal in the entire section would then be equal, whereas with the section proposed the spaces back of the channels would require for the bottom plates a section 50 per cent. or 75 per cent. greater than those forming the top chord over the flanges of the channels. The necessity of built-up sections for use in bridge floors, other than those contained in the mill books, does not seem to me to be of special interest or importance."

In a still later letter Mr. Barbour defends his channel section, stating that it can be used to greater depths than Z-bars.

About this time (1892), there was built the plate girder bridge carrying the New York, Providence & Boston Railroad into the station at Worcester, Mass., including a floor very different from anything that had yet been devised. This floor, shown on Plate II, Fig. 3, was designed and patented by Mr. J. R. Worcester, Chief Engineer of the Boston Bridge Works. It consists of a series of parallel V-shaped troughs of plates and angles running transversely and connected to the webs of the girders by angles and brackets. Along the center line of the bridge, the floor is stiffened by V-shaped plates fitting into the troughs and secured by angles, as shown in the small sketch accompanying the drawing. The troughs are filled with concrete to a height of 5 inches above their tops, upon which is laid the ballast and track in the usual manner.

All the bridges of the Adirondack & St. Lawrence Railroad have solid floors, those under 10 feet span having rail floors, from 10 feet to 34 feet having longitudinal troughs, and over 34 feet span transverse troughs. The Trenton Falls bridge on this road is a three-span structure, completed during the winter of 1892–93, the central span being 100 feet in length and fitted with the square form of trough already described. The other two spans are shorter and have a different type of floor trough, shown on Plate II, Fig. 5. It consists of a trough similar to the other but shallower and built without the vertical plates, the vertical legs of the angles being long enough to be riveted directly together.

Few of the floors up to this time had been especially designed to be

water-tight so as to be suitable for overhead street crossings. In some cases this had been effected, but the conditions had not been many where such were required. But as soon as solid floors began to be contemplated in connection with designs for the abolition of grade crossings in cities, the problem of water-tight bridge floors provided with proper drainage naturally arose and became an important one.

Among the first to build a system of overhead bridges was the Illinois Central Railroad, when, during 1892 and 1893, that road carried out its great task of elevating its main tracks within the city limits of Chicago. The form of floor adopted for these bridges was the Pencoyd Section, chiefly because that was the only suitable ready rolled shape, and limited time prevented the consideration of other more complicated forms. These trough floors are 6 inches deep and all rest on shelf angles riveted to the webs of the girders. The successive changes in the method of laying the track on these floors and the reasons determining these changes are very interesting.

The original plan for bridges not over 13 feet wide, center to center of girders, contemplated putting asphalt in the troughs and placing the ties upon this. But the heavy traffic during the World's Fair prevented this from being accomplished either at first or afterward, so that for over a year the tracks were operated with the ties resting directly on the lower part of the troughs without any cushion, just as they were temporarily placed at first. During this time the accumulation of sand, gravel ballast, cinders, etc., around and under the ties was assisting immensely in the rusting process, and during 1894 the tracks were raised and the ties placed on the *upper* part of the troughs. This is the present state of these floors, leaving the metal free to be cleaned and painted when necessary, and always exposed so that no rust can escape discovery.

A different method of laying the track on bridges wider than 13 feet, center to center, consists of fastening the rail to longitudinal stringers by Marshall clips, the stringers being about 4 inches high and placed between two 8-inch deck beams riveted to the floor, thus forming an inner and outer guard rail. This design is so worked out that the rail is insulated on wooden bearings, etc., so that an electric signalling apparatus will work automatically with a track circuit.

Still another way that the Illinois Central is using this same trough, though of deeper section, is to cover it with ballast to a depth of 2 inches over the upper parts and lay the ties and rails thereon without guard rail.

These floors are all provided with drainage holes through the troughs at each end, near the girder connection; and the original plan included the placing of gutters under the girders leading to down spouts near the column supports where the floors were used over streets.

The Gaspee and Promenade streets bridges of the Boston and Providence Railroad, near the Providence station, were completed in the fall of 1894. The shape of the floor used is shown on Plate II, Fig. 4, and was a complete departure from any existing patterns. The conditions surrounding the construction of these bridges required a possible change in the location of the tracks after completion, and this condition, together with the large area of the bridge, made it impossible to so treat the structure as to shed water at the ends or sides. To support the assumed loads a series of troughs 10 inches deep was required. The deepest available rolled troughs with tight bottom at that time being only 6 inches, and even this, having awkward features in shop construction, led to the design adopted. The inventors and patentees of this floor are Messrs. George B. Francis and E. P. Dawley. The particular merits claimed for their floor are: (1) Simplicity in rolling; (2) adaptability to power riveting; (3) elimination of difficulty in accurate spacing, center to center of shapes; (4) smooth base on which to rest; (5) avoidance of rivet holes in bottom or tension flange when treated as a girder; (6) water-tight bottom, and (7) a variability in height within reasonable limits while preserving all of the other features. The shapes are so placed that the water collected in the troughs is discharged at the ends, where they rest on shelf angles on the webs of the intermediate longitudinal box girders, and flows into gutters and down spouts placed for the purpose.

The Chicago and Northwestern Railway adopted a floor differing again from existing styles. It was designed by Mr. Louis H. Evans and consists, as shown on Plate II, Fig. 7, of floor beams built of a vertical plate and two channels 10 inches deep, with heavy top and bottom plate forming an I-section and connected to the main girders by the ordinary gusset plates. Upon these beams is laid plate-decking $\frac{5}{16}$ inch thick. The rails are carried on wooden blocks laid in trough stringers built of a plate and angles, the angles forming a built Z-bar. It was originally intended to use Z-bars in this place, but the plan was afterward changed to the one shown. The troughs are not water-tight, having no bottom plate except at the ends, where a short plate is riveted through the bearing plate to the shelf angle to furnish end bearing for the rail blocks. These blocks raise the rails to clear the top plates of the beams, but no provision appears to have been made to hold them firmly in place. Outside the trough a continuous angle is riveted to the plate-decking to serve as a guard-rail.

The Denver & Rio Grande Railroad has lately gotten out a standard shallow floor for girders that is in principle somewhat like that of the Northwestern floor. The floor, designed by Mr. J. C. Bland, is shown on Plate II, Fig. 6. It is designed for the heaviest engine concentra-

tions, and the details have been worked out with care. In this floor also, there are floor beams of plates and channels, but in this case they are placed backs outward with two cover plates over the top and angles riveted to the lower part of the webs to support the troughs. The entire width of the bridge is covered by these longitudinal troughs built of Z-bars 5 inches deep, connected by horizontal plates above and below. The bottom plates of the troughs stop short of the connection angles and within the trough at this point a short angle is riveted to the lower flange of the Zs, thus leaving a slot ½ inch by 3½ inches, through which the drainage water escapes. The troughs are filled with bituminous concrete nearly level with the tops of the ties, or even with the tops of the short check angles mentioned above. The ties rest directly upon the troughs and are not dapped down upon them, but the guard rail, instead of being dapped over the ties in the usual manner, is let down upon them by dapping ties and guard rail each one inch. Ties and guard rail are then bolted down upon the troughs.

The Lake Shore & Michigan Southern and the Chicago, Rock Island & Pacific Railways have been doing considerable work during the past two years, requiring the use of water-tight solid floors, in the elevation of their tracks within the city of Chicago. At first the form of floor used was practically the same as that so generally in use on the New York Central: viz., square troughs built of plates and angles. The depth of this floor is 10½ inches and the troughs are spaced 21½ inches center to center. The flooring fits between the lower chord flanges of the girders with a clearance of one inch on each side for drainage, and its under side is on a level with the bottom of the girder flange. The floor is reinforced at the ends and provided with plates and angles which rest on the vertical legs of the girder flange angles and rivets to the web of the girders. It is also stiffened against the girders with gusset plates and angles riveted to the tops of the corrugations and the vertical web stiffeners. Upon the floor, and riveted to it through the reinforced angles on each side of every corrugation, are rail plates under each rail, and the rails are fastened directly to those plates by special clips. Gutters to catch the drainage water are placed under each girder, leading to down spouts at the column supports emptying into the street gutters.

But during the past year the design has been entirely changed and all the bridges built within the past year have been supplied with a very different floor. It consists (see Plate II, Fig. 8), of 10-inch by 33-pound I-beams cut at the ends to an angle of about 60 degrees, with 9¼-inch by $\frac{7}{16}$-inch hanger plates riveted to each end in the shop by means of angle lugs riveted to the webs. These floor beams are riveted to the girders in the field with five rivets connecting each hanger to the web, and with two rivets to one of the bottom cover plates of the main girder,

made wider for this purpose, for side stiffness. A continuous sheet of $\frac{5}{16}$-inch steel plates is placed upon the floor beams and riveted to them. It is riveted to the sides of the girders with a continuous seam through the angle irons, provided and spliced at the joints with 5-inch by $\frac{3}{8}$-inch lap plates placed below the surface. The girders are cambered $\frac{3}{8}$ inches and the drainage is from the center to the ends of the bridge, and at each end the sheet covering is finished with an angle iron, and provided with a gutter of $\frac{1}{8}$-inch sheet steel, which drains into a groove cut into the coping of the masonry and from there into the earth fill behind the abutments.

Upon the plate covering of the floor, and riveted to it and the floor beams, are laid the rail plates and angle guard rail. The rail plates are alternately arranged for rail fastenings and for rail bearings only. The rails are fastened to these rail plates by means of special close-fitting clips bolted snugly to place.

Both the foregoing plans were designed by Mr. Albert Lucius, Consulting Engineer.

Of late the New York Central has also adopted a similar floor as a standard for through girder bridges. In their plan, however, the beams are connected directly to the webs of the girders by heavy angles and they are covered with plates only between the guard rails, which are made of angles laid each side of each rail, flaring out at the ends of the bridge. The rails are held in place by a similar clip and are separated from the metal work by indurated fibre, thus insulating them for electric signalling purposes.

The writer has lately had occasion to design a solid floor for a system of elevated tracks over street crossings, which is illustrated by Fig. 9, Plate II. This floor consists of transverse beams of I-section built up of 3-inch by 3-inch angles and 12-inch web plates, and extending the full width of the bridge. These beams are connected to the girders by means of 6-inch by 6-inch angles which rivet to the web plates of the beams and directly to the main girders without the aid of gusset plates. On top of the beams continuous floor plates are riveted, making an unbroken water-tight deck. The rails are attached directly to the iron work, resting on bearing plates about $\frac{1}{2}$ inch thick and, when necessary for insulating purposes, indurated fibre plates may be placed between the rails and the $\frac{1}{2}$-inch bearing plates. The floor plates with their splices are placed lengthwise of the bridge, so that, with the assistance of the camber or the grade or both, the water may drain to the ends of the bridge and there be taken care of by properly arranged drains. It will be noted that this floor is made up of the most readily obtainable material, plates and angles, and the workmanship is of the simplest character.

A review of the history of the design of solid metal railroad bridge

floors reveals a curious fact. The earliest design on record is composed of built beams supporting an iron decking, and the latest forms introduced are quite similar; a remarkable illustration of the old saying that "history repeats itself."

It seems proper here to call attention to the fact that a number of our larger railway systems, principally those in the East, are obtaining solid floors in a great many cases by replacing their shorter iron spans by masonry arches, which enables them to carry their road-bed uninterruptedly from bank to bank.

In designing a solid floor, consideration should be given to the following features: Accessibility for examination and painting; facilities for thorough and rapid draining; use of shapes and sizes readily obtainable from the mills; simplicity of shop construction; cheapness of first cost and cost of maintenance; convenience of changing location of track to accommodate switches, frogs, etc.; and the attachment of floor to girders should be effective, simple, and as direct as practicable. Eccentricity of connections should be avoided. The floor should be arranged to carry a derailed train with as little damage to it or the bridge as possible.

Of the designs illustrated, doubtless some are better suited for certain locations than others. The designer should thoroughly consider the particular case in hand, allowing, among other things, for the current prices of the various shapes, and giving due consideration to all the factors contributing to the excellence of his structure. Time will, in the future as in the past, undoubtedly bring about the "survival of the fittest."

As to highway bridge floors, there is less to be considered. European engineers are before us also in the use of solid floors for highway bridges, and most of the highway bridges of England are, and have been for many years, built with permanent floors. The forms in use are varied, plate iron, buckle plates, corrugated, and arched plates being mostly used, though some of the simpler forms of troughs are not infrequently met with. The trough form of bent plates used on the Tower Bridge, London, has already been mentioned. The highway bridge over the Tay, Scotland, has a similar floor. The Cobden Foue Bridge, at Southampton, has a floor of corrugated iron supported on shelf angles riveted to the floor beams, the shelf angles being curved to fit the crown of the roadway. The corrugated floor is of ¼-inch metal, and the corrugations are 6 inches deep, covered with concrete and wooden paving blocks.

In this country permanent floors are all of comparatively recent design. The Callowhill Street Bridge, over the Schuylkill River at Philadelphia, was built in 1875. Its floor is probably the earliest of the permanent kind built in America. It consists of square buckle plate flooring, riveted to light beam stringers at the sides and at the

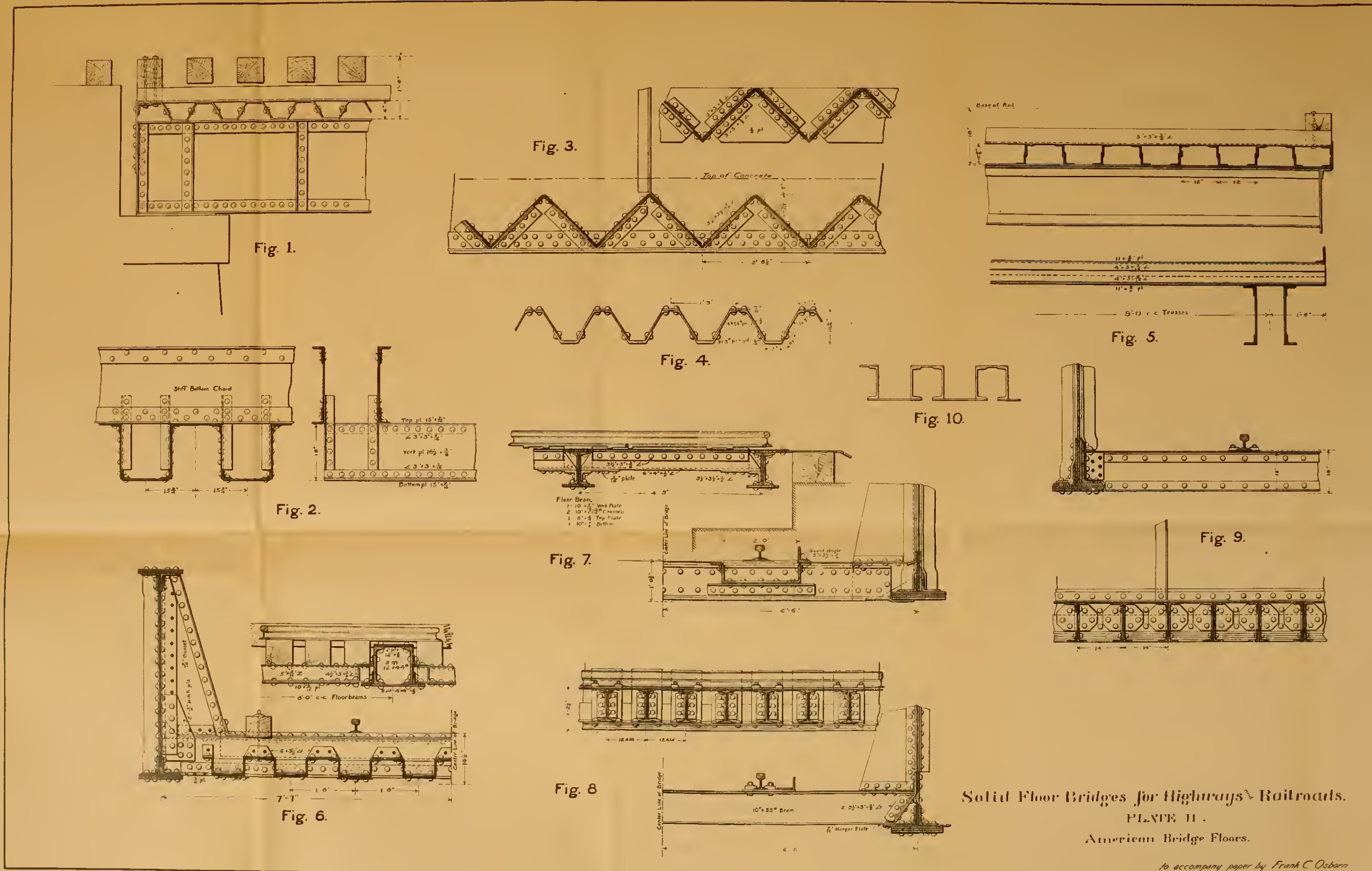


Fig. 1.
Fig. 2.
Stiff Bottom Chord
Top pl 15" x 7/16"
Bottom pl 15" x 7/16"
Fig. 3.
Top of Concrete
Fig. 4.
Base of Rail
9'-0 c c Trusses
Fig. 5.
Fig. 10.
Fig. 7.
Floor Beam.
Centre Line of Bridge
Guard Angle
Fig. 9.
Fig. 6.
6'-0" c-c Floorbeams
7'-7"
Fig. 8
10" x 33# Beam
Solid Floor Bridges for Highways & Railroads.
PLATE II.
American Bridge Floors.
To accompany paper by Frank C Osborn

ends to T-bars which cross the beams. The buckle plates are 3 feet square and ¼ inch thick with a total rise of 2½ inches. The bridge was built by the Keystone Bridge Co., and the plates manufactured for it are probably the first made in this country.

A ribbed steel arch bridge at East Rock Park, New Haven, Conn., was built about 1889 with a floor of ordinary floor-beams covered with creosoted pine plank 4 inches by 12 inches laid longitudinally, which was in turn covered with 3-inch by 12-inch creosoted pine planking laid transversely. Over this was laid a double thickness of tar-paper covered with a wearing surface of asphalt 2½ inches thick. The bridge proves very rigid and gives good satisfaction.

But even with all this care to obtain a stiff and permanent floor, its design is eclipsed by the paved floors on metal plates, which have since been used so often in spite of some opposition. The Carnegie Steel Co. have had a stock shape of curved plate flooring since 1882, which has been used in various cases.

In the summer of 1891, Mr. Carl Gaylor said in a paper before the Engineers' Club of St. Louis on "Viaducts across Railroad Tracks":

"In regard to floors, we have gone through the usual evolution from wooden joists and planking to wooden block pavement on planks carried by steel stringers. Permanent floors seem after all, on account of their great weight, to be a thing of the far future. As a step in this direction may be designated the covering of the Forest Park Boulevard Bridge over the Wabash tracks with Portland cement concrete arches between steel girders."

The Baltimore Street Bridge at Cumberland, Md., two plate girder spans 72 feet long each, has a floor consisting of cross girders riveted to the main girders and spaced 14 feet 5 inches apart. These support three lines of stringers, which divide the space between the girders into four openings about 6½ feet wide. Upon the stringers is laid No. 210 Pencoyd corrugated flooring and a layer of concrete is filled in on this to a depth of 7 inches. Upon the concrete a 2½-inch layer of Trinidad asphalt forms a wearing surface.

In 1892, when the grade crossing question was being studied in Buffalo, consideration was given to buckle plate form, and in a letter describing it at that time, Mr. Henry Goldmark said:

"This shape of iron has only recently been introduced into this country and I believe only two firms, viz., the Keystone and Pencoyd, have the dies for making the buckles. There is, however, no patent for covering the device, and for any larger piece of work, I fancy other mills would put in the plant necessary to make them. The buckle itself varies from 2 feet 9 inches to 3 feet 9 inches in width and is made in some three or four intermediate sizes, all the buckles being square. The flat

part at the edge of the buckles (through which the rivets pass) can be made of varying widths, from 2 inches or 3 inches to perhaps 6 inches wide. This gives a fair amount of variation in spacing the longitudinal stringers carrying the plates. As to the depth of floor, the tops of the stringers can be made to coincide with the top of the floor beam so that the depth of the floor beam governs the depth of the entire floor. I think a pretty good floor can be built with as little as 6 inches of covering (concrete and asphalt) over the tops of the stringers. This gives 3 inches or 4 inches over the top of the buckle. I do not think that we ought to have any less."

In making the first statement above, Mr. Goldmark very probably referred to buckled plates with three buckles in each plate, as now so generally used; for, as noted in the description of the Callowhill Street Bridge, buckled plates having one buckle to each plate were manufactured by the Keystone Bridge Company as early as 1875.

Since then buckle plates have been used very frequently. Three prominent cases are, the Walnut Street Bridge over the Schuylkill River, Philadelphia, where buckle plates $\frac{3}{8}$ inch thick are used, supporting a concrete and granite block pavement; the Front Street Viaduct at Columbus, Ohio, where the buckle-plate flooring is covered with concrete, sand, and brick pavement; and the Selby Avenue Bridge at St. Paul, Minn., on which buckle plates are used only at the cable-car tracks in the middle of the roadway, covered with concrete and pine blocks.

The investigation of the grade crossing question in Buffalo is very interesting. A number of different designs were considered and sketches representing the same are shown on Plate III, Figs. 1 to 5. Mr. George E. Mann, Chief Engineer Grade Crossing Commission, has very kindly furnished the writer with these sketches and data concerning the same. The floor adopted for this work was Pennsylvania Steel Company's Section, Fig. 4. The merits of this floor over the others, as found by the Board of Commissioners, are as follows:

First. Its form of construction, giving lateral rigidity, vertical stability to the floor beams, and moderate weight per square foot of area in the required limit of depth.

Second. For an asphalt surface the form of trough was considered better to hold the "binder" against the tendency of rolling forward under wheel-action in extremes of high temperature than either forms 1 or 5.

Third. Its cost compared with other forms of floor.

The width between bridge trusses is 42 feet and the depth of floor 2 feet 2 inches. For such a length of floor beam with this shallow limit of depth, it was considered unwise to adopt either plans 2 or 3,

owing to their increased weight and so necessarily requiring heavier and more expensive trusses.

Mr. Mann is of the opinion, however, that with greater depth of floor allowable and shorter distance between trusses, the concrete or the Melan arch plans (Figs. 2 and 3) are excellent. The following table gives a comparison of these several sections:

No.	Description of System supporting Floors.	Dead Load per sq. ft. of Floor.	Total cost per sq. ft.
1.	—Section M 31, Carnegie Steel Co. . .	85	$1.85
2.	—Melan Arches	190	2.00
3.	—Concrete	250	2.78
4.	—Troughs, Penna. Steel Co.'s Section	100	2.00
5.	—Buckle Plates	76	1.76

All metal work assumed for comparison @ 3 cents per pound in place.

An interesting solid floor was built on the 180 feet arch span Foot Bridge across the "Lagoon" in Lincoln Park, Chicago, in 1894, W. L. Stebbings, engineer. The floor beams are placed at panel points 18 feet apart, there being at the center of the span two beams placed near together with the expansion joint between them. Beginning at each of these center beams, a series of two groups of four steel wires each is carried back over the intermediate floor beams towards each end of the span. The vertical planes passing through these groups are 1 foot apart, horizontally in a direction transversely across the bridge. These groups of wires are filled around with concrete covered with 1 inch of granitoid top dressing.

Some time ago Mr. A. L. Schulz designed a floor for a highway bridge in Pittsburg, consisting of 8-inch channels laid flatwise, resting on the edges of the flanges, making a continuous flat deck, the flanges giving the vertical stiffness.

Corresponding to the practice of some of the railways of introducing masonry arches to obtain uninterrupted road-bed over waterways and other openings, a number of localities have recently had constructed arches of the Melan type, which system has been introduced by Mr. Fr. Von Emperger, of New York and Vienna. This system involves the bedding of a series of longitudinal I-beams in the intrados of an arch of concrete, the ends of the beams passing into and being entirely surrounded by the concrete of the arch abutments. This plan makes the use of any kind of paving a very simple matter, and the construction permits of obtaining ornamentation and architectural effect at comparatively slight extra cost. Mr. Von Emperger also favors the use of similar concrete and I-beam arches between floor beams on steel bridges, claiming for this form: freedom from necessary care and frequent painting of metal surfaces, great strength and stiffness, and 30 per cent. less cost than the use of Carnegie's curved plate form for the same span.

In closing, the writer submits herewith a sketch of the floor he designed during the past year for the South Rocky River Bridge, near Cleveland, O. (see Plate III, Fig. 6). This bridge is 1219 feet total length, center to center, and has a 32-foot roadway, with provisions for a double track electric railway line. It will be noticed in this bridge that the buckle-plates are placed the other side up from the usual practice, thereby saving considerable weight of concrete filling and decreasing the thickness of the floor proper, while still preserving all the strength. The method of supporting the track stringers to preserve the crown of the roadway has proven very satisfactory. The drawing also shows, incidentally, the design adopted at the ends of the floor beam. Conditions required that, although no sidewalks were to be built immediately, provision should be made for their addition at some future time. The sidewalk brackets are, consequently, designed for a greater length, but are cut off in such a manner that about six feet more can be added to their length at any time by cutting off the curved end beyond the splices and splicing on a new section. While brick will be used for the pavement of this bridge, the design is just as well adapted to asphalt, granite, or wooden blocks.

The writer takes great pleasure in acknowledging here the valuable service rendered in the preparation of this paper by Mr. Bernard L. Green, who has conducted the correspondence, prepared the drawings, and written a large part of the text.

Acknowledgments are also due the following gentlemen who have kindly furnished drawings and given other information contributing to the value of the paper:

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Mr. L. B. Bidwell, Chf. Engr. N. Y. & N. E. R. R.
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Mr. Louis H. Evans, Div. Engr. C. & N. W. Ry.
Mr. Julius Kruttschnitt, Gen. Mangr. So. Pac. Co.
Mr. Albert Lucius, Cons. Engr.
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Mr. J. F. Wallace, Chf. Engr., I. C. R. R.
Mr. F. W. Wilson, Bridge Engr., N. Y. C. & H. R. R. R.

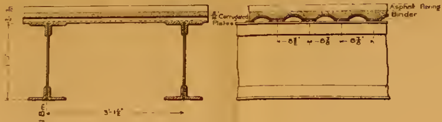


Fig: 1.
Corrugated Floor. Section M 31, Carnegie Steel Co

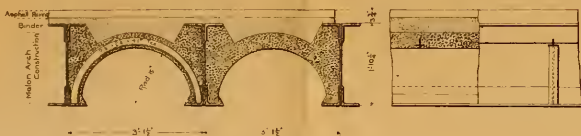


Fig: 2.
Melan Arch Construction.

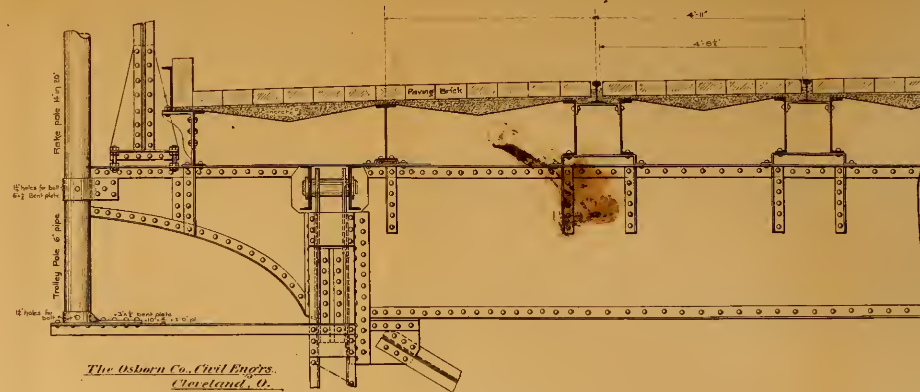


Fig. 6.
South Rocky River Bridge.
Cleveland Ohio.

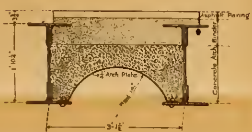


Fig: 3.
Concrete Arch.

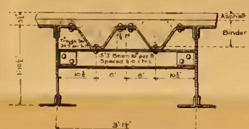


Fig. 4
Trough Floor, Penna Steel Co. Section

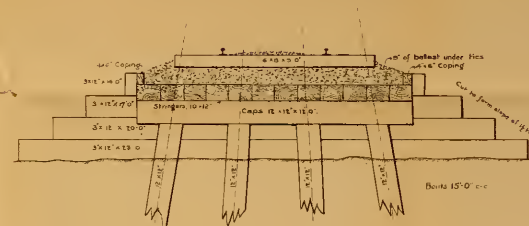


Fig: 7.
Ballasted Trestle, Southern Pacific Co.

Fig. 5.
Buckle Plate Floor.

Solid Floor Bridges for Highways & Railways.
PLATE III.
Highway Bridge & Trestle Floors.

to accompany paper by Frank C Osborn

VAN BUREN STREET ROLLING LIFT BRIDGE, CHICAGO, ILLS.

By Warren R. Roberts, City Bridge Engineer, Member Western Society of Engineers.

[Read before the Society, March 20, 1895.*]

INTRODUCTION.

With the opening of the new bridge, over the South Branch, at Van Buren Street, a work was completed which had caused the engineers and contractors a great deal of care and anxiety in its construction and not a little solicitude as to its success. There were many difficulties to be overcome both in the design and in the construction of this bridge. Its completion and successful operation indicate that these difficulties were overcome, not to say that this bridge cannot be improved upon. This was the first bridge made from this design, which fact is sufficient reason why improvements should be made if a second one were to be built.

The design of bridges, and especially of movable bridges, has passed through a state of evolution. The common swing bridge has reached its present state of perfection by a process of development, due to which fact it is, no doubt, the most desirable type of drawbridge. Whenever an engineer selects a bridge of new design, he must be willing to pay for the general good to be derived from the introduction of the new type.

Before beginning the consideration of this Rolling Lift Bridge, the conditions to be fulfilled at the bridge site and the governing requirements should be stated, for it may be assumed that under conditions favorable to the swing bridge no other type would have been considered.

CONDITIONS AND REQUIREMENTS.

The old bridge at this site was a swing bridge giving two channels, an east one of about 55 feet, and a west one of about 60 feet. The east channel was the one principally used, the west one being too shallow and crooked to be navigated by anything except tugs and other small craft. This old bridge was only 34 feet wide over all, having one roadway of 20 feet and two sidewalks of 7 feet each.

The first bridge considered for replacing this old draw was a swing bridge, with equal arms of 110 feet each, giving a clear channel on the east of 67 feet and on the west of 55 feet. The total width of this pro-

* Manuscript received December 14, 1895.—*Secretary, Ass'n of Eng. Socs.*

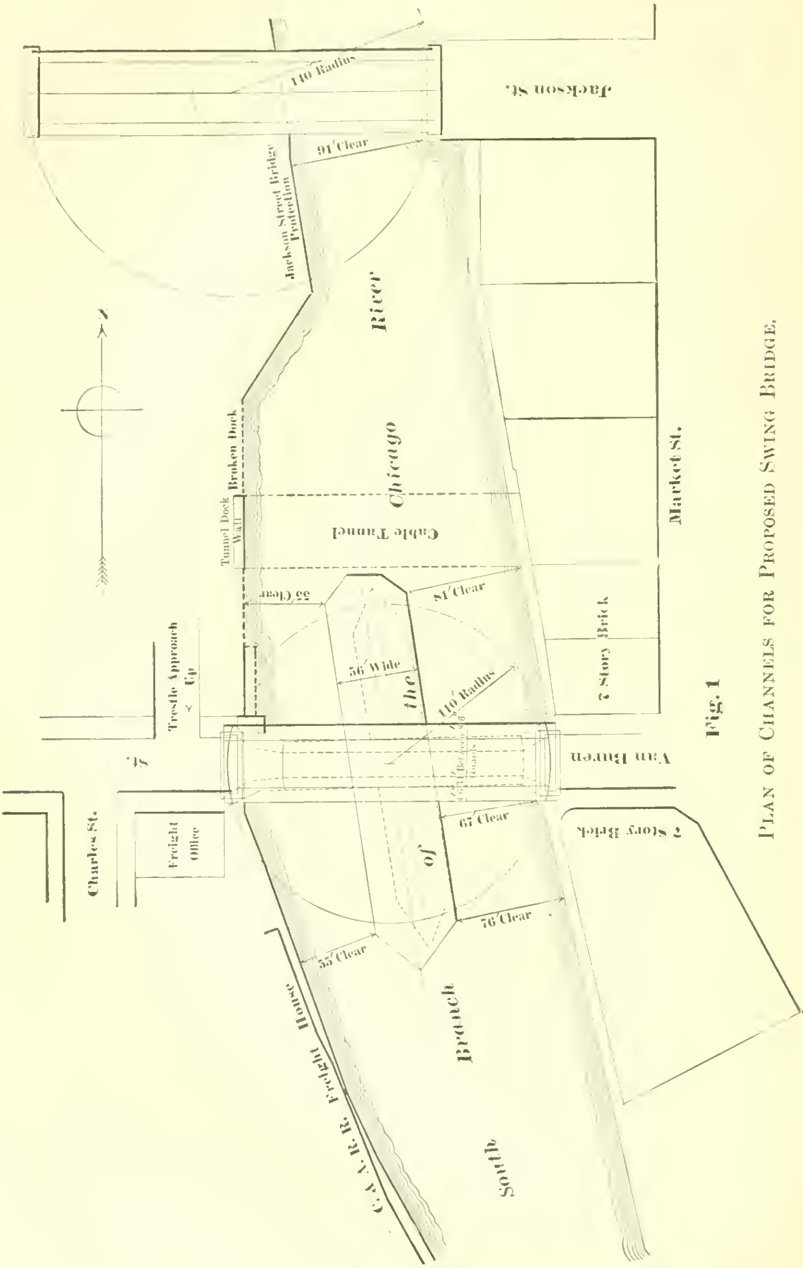


Fig. 1

Plan of Channels for Proposed Swing Bridge.

posed bridge was 51 feet, having one roadway of 34 feet, and two sidewalks of 8 feet 6 inches each. The east channel was thus increased from 55 feet to 67 feet, and the west reduced from 60 feet to 55 feet, with an increased width of bridge of 17 feet. To accomplish this it was intended to move each abutment back a considerable distance. This change of channels, location of abutments, etc., is clearly shown in Fig. 1. The old bridge and protection are shown in broken lines and the proposed bridge in full lines.

At the time these changes were being considered, the Metropolitan Westside Elevated Railroad Company was considering means and methods of crossing the river, and it was proposed by the city to make this swing bridge a double-deck structure, with a roadway below and the elevated railway above. But this plan for a swing bridge was abandoned for the reason that a straight channel was insisted upon by the United States Government, from Jackson Street Bridge to the turn in the river below Van Buren Street, with the clear width of this channel of not less than 100 feet. Such a channel could not be obtained by means of a swing bridge, without placing the center pier considerably to the west and making the draw much longer, which was not practicable on account of damages to the adjoining property.

Several other schemes, some for a combined bridge and others for separate bridges, were considered, but none of them fulfilled all the requirements.

It was while engaged upon an investigation and elaboration of certain of these schemes for the Metropolitan Railway, that Mr. William Scherzer devised the type of bridge we are considering. After a careful investigation of its merits, as compared with those of other types of lift bridges, it was decided by the management of the Metropolitan Company to adopt this bridge, and Mr. Scherzer was entrusted with the preparation of the detail plans. The Metropolitan Company then proposed to the city that this type of bridge be used at Van Buren Street, and that they be allowed to cross the river between Jackson Street and Van Buren Street on a similar bridge. This proposition was accepted by the city (and approved by the Secretary of War, November 16, 1893), and the bridge at Van Buren Street was constructed from Mr. Scherzer's design.

The two points of merit which this bridge possesses, and which make it especially suitable for the place are: First, that it moves in a vertical plane, thereby giving room for it, the Jackson Street draw, and for the Metropolitan bridge, which are all in close proximity; and second, having no center pier, the clear channel of 91 feet at Jackson Street is maintained at Van Buren Street. The channel at this place and the present location of the bridges are shown in Fig. 2.

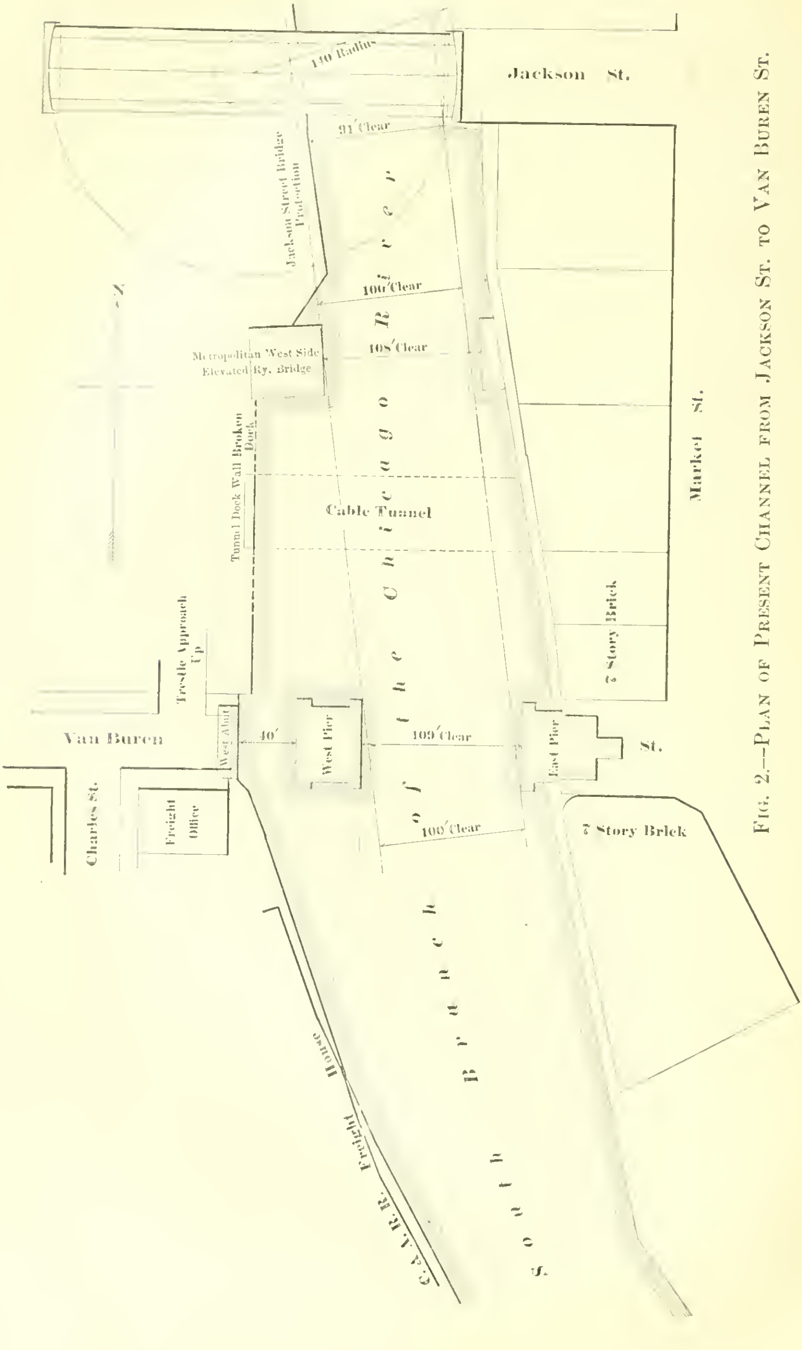


FIG. 2.—PLAN OF PRESENT CHANNEL FROM JACKSON ST. TO VAN BUREN ST.

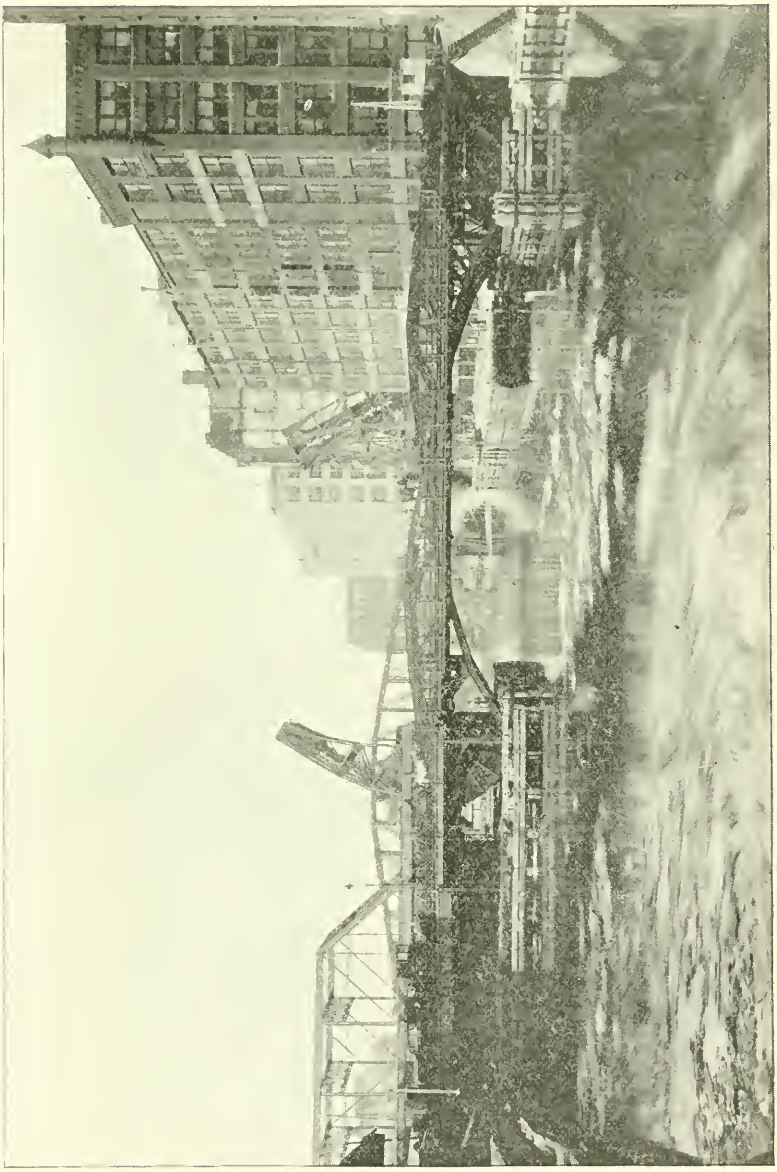


Fig. 3.

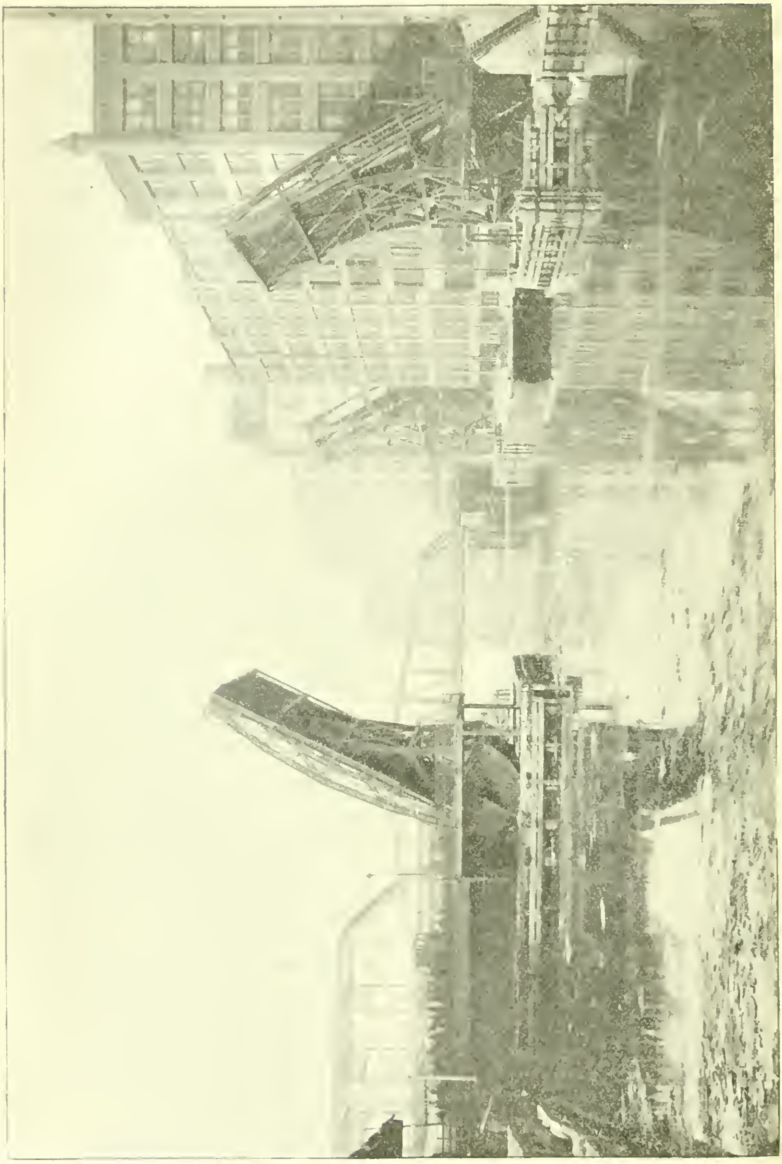


Fig. 4.

GENERAL DESCRIPTION.

The peculiar motion of the bridge in operation has given it the name of "rolling-lift" bridge; each half of the bridge rolling backward and upward upon three segmental girders at its base.

Fig. 3 shows the bridge closed, ready for traffic. This illustration was produced from a photograph of the bridge, taken after completion, and correctly represents the bridge. The two movable parts of the bridge are in every respect alike. The approaches are not alike. On the west the abutment and pier are separated by 40 feet, and the space between these is bridged over with plate girders and forms a room for the machinery and motors. On the east side the abutment and pier are combined in one piece of masonry, and space for the machinery was provided by building a room in the abutment. In each of these rooms are placed the motors, air pumps, air reservoirs, and other machinery necessary for the operation of one half of the bridge; *and each half is operated independently of the other.*

On each approach, on top of the center roadway girder, is placed an operator's house. The operator has here before him the air valves for operating the gates, signals and brakes, the controller for operating the motors, and other apparatus for the complete control of one-half of the bridge.

Fig. 4 shows the bridge open, giving a clear channel of about 100 feet between abutments. The time required for opening the bridge is about thirty-five seconds, and for closing about twenty-five seconds, which time could be reduced if it were desirable. In this view the Metropolitan Railway "rolling-lift" bridge, and Jackson Street swing bridge are both shown in the background.

In Fig. 5 is given a side elevation of the west half of the bridge when open, showing very clearly the position of the segmental girders for this position of the bridge. A study of this view will help to understand the peculiar motion of the bridge. It will be seen that there is no sliding motion, and no hinge motion, as is generally expected by those seeing the bridge in operation. It is a true rolling motion, with no friction, except rolling friction, and the friction at the pin connection of the operating strut and possibly a little in the meshing of the racks under the segmental girders.

Fig. 6 gives a view looking east upon the west half of the bridge when open. We have here very forcibly presented the amount of wind-surface offered when the bridge is fully opened. The area above the line of the roadway amounts to about 3,300 square feet, and a pressure of 18 pounds per square foot gives a pull in the operating strut of 165,000 pounds.

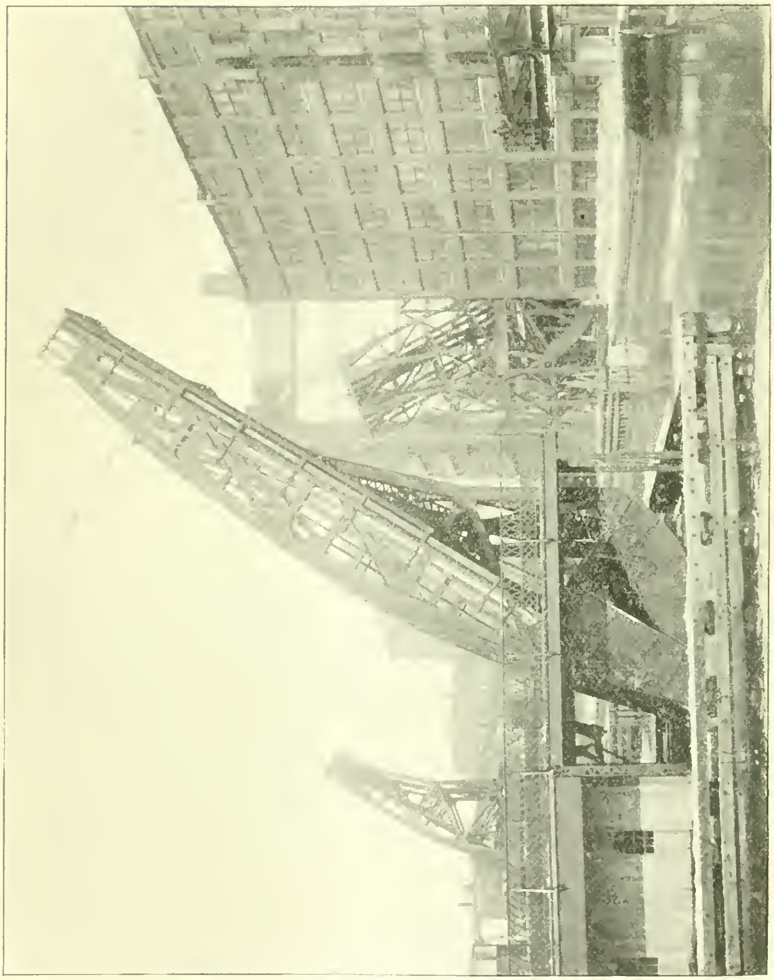


Fig. 5.

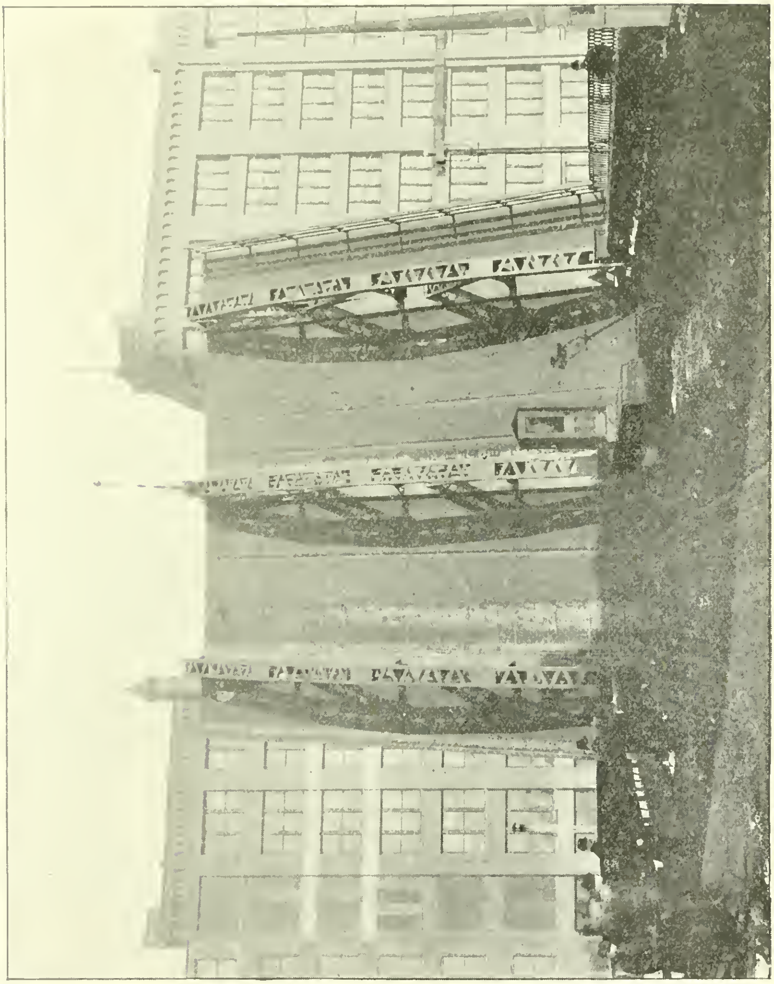


Fig. 6.

This is the maximum stress for which the operating strut and the machinery were figured; it being assumed that traffic on the river would stop with a wind which would give 18 pounds per square foot. Mr. Trautwine, in his "Pocket-Book," gives 18 pounds per square foot as corresponding to a violent storm of 60 miles per hour.

In Fig. 7 the horizontal bracing and the vertical bracing between the segmental girders are clearly shown. This vertical bracing and the lower panel of the horizontal bracing were not riveted up until both sides of the bridge were completed, lowered into a horizontal position and the adjustments made between the two parts.

The adjusting was one of the most interesting parts of the erection. When the bridge was first lowered into a horizontal position, so that the two parts of the north truss came together properly, it was found that the east half of the center truss was an inch or more above the other half, and that the east half of the south truss was some two inches or more above the west half. The two parts of all three trusses were brought into the same plane by the adjustments under the tail girders, and the vertical bracing was then riveted up.

At the time this vertical adjustment was made there was also a lateral error of about the same amount, the ends of the trusses on the east portion coming about 1 to 1½ inches too far north to match those of the west portion. The two parts are raised, and a transit told us that the trusses in the west portion stood very nearly in vertical planes, while those of the east portion leaned about 1 to 1½ inches to the north. Therefore we riveted the lateral bracing in the west portion as it stood. The upper end of the east portion was then pulled over 2 inches to the south by attaching cables to the upper and middle parts of the trusses, and the lateral bracing was riveted while the cables were attached. When the cables were released and the two parts again lowered, they came together perfectly.

SUBSTRUCTURE.

The construction for each of the three parts of the substructure was essentially the same; the foundation being formed of piles, the body of the structure of concrete and the top of Bedford masonry.

The foundation piles were driven about 3 feet centers over the entire area to be occupied by each piece of masonry. These piles were of Norway pine, 50 feet long and not less than 10 inches in diameter at the small end. They were driven nearly to the water line and sawed off 17 feet below it, leaving 33 feet of the piles in the foundation. The west abutment was built first, then the west pier, and lastly the east pier and abutment. While the driving of the piles for each part was progressing, the caisson for the same part was being built at dock

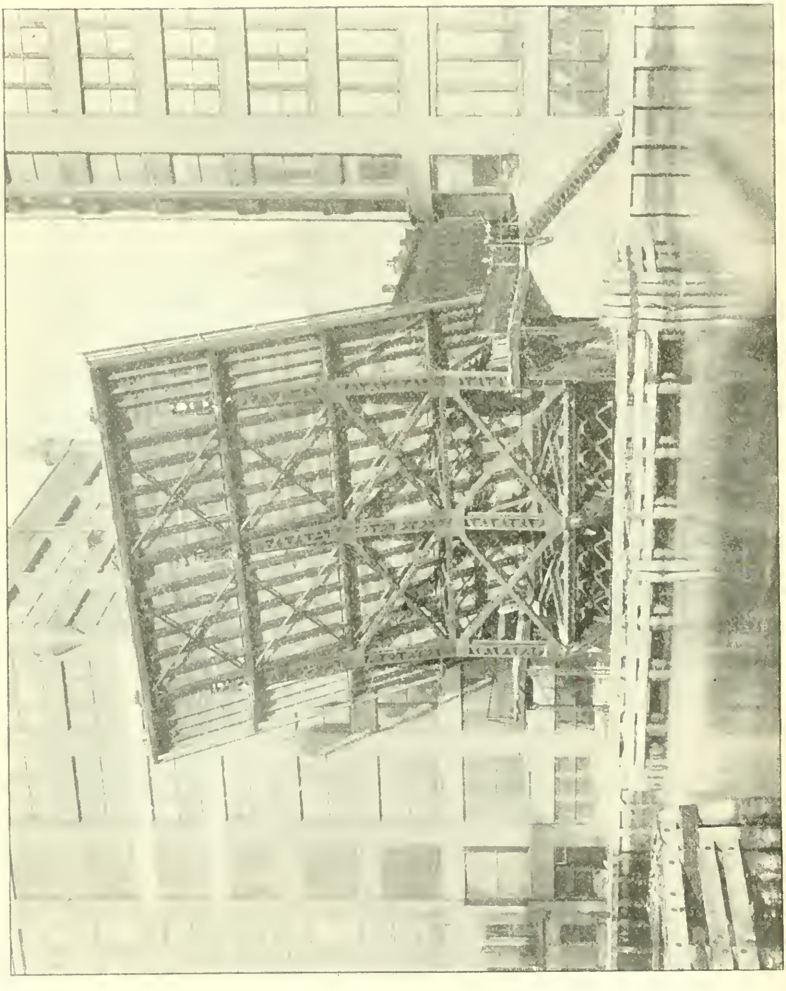


Fig. 7.

and, when partially filled with concrete, was floated into position. The concreting was then continued, and the sides of the caisson were continually built up to keep progress with its sinking until it came to a bearing on the piles. The concrete used was machine mixed, with one part of Portland cement, and two and one-half parts of sand and five parts of broken limestone.

The first work done on the west abutment was to construct the coffer-dam and connect it at each end with the dock. (See Fig. 8.)

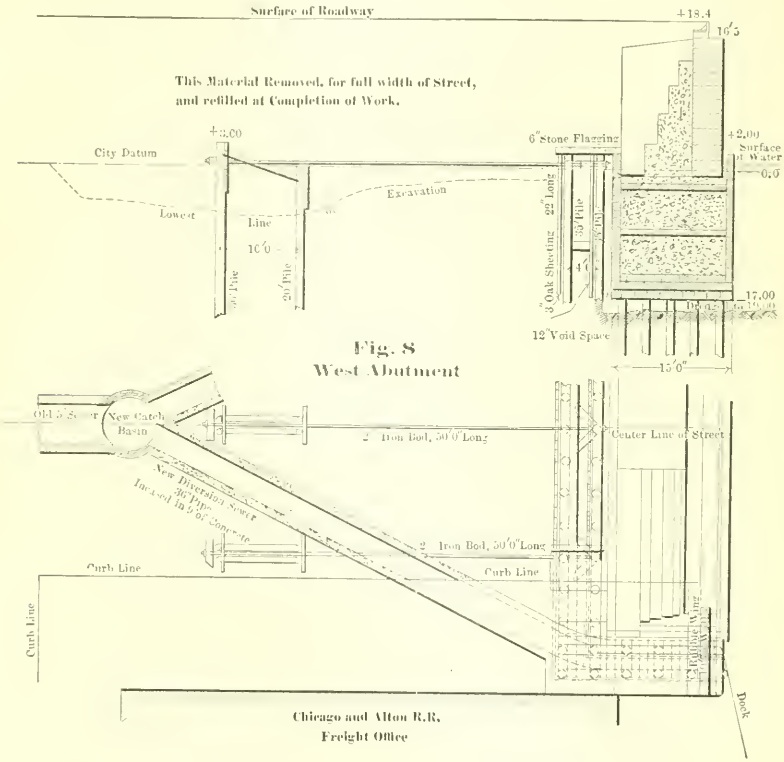
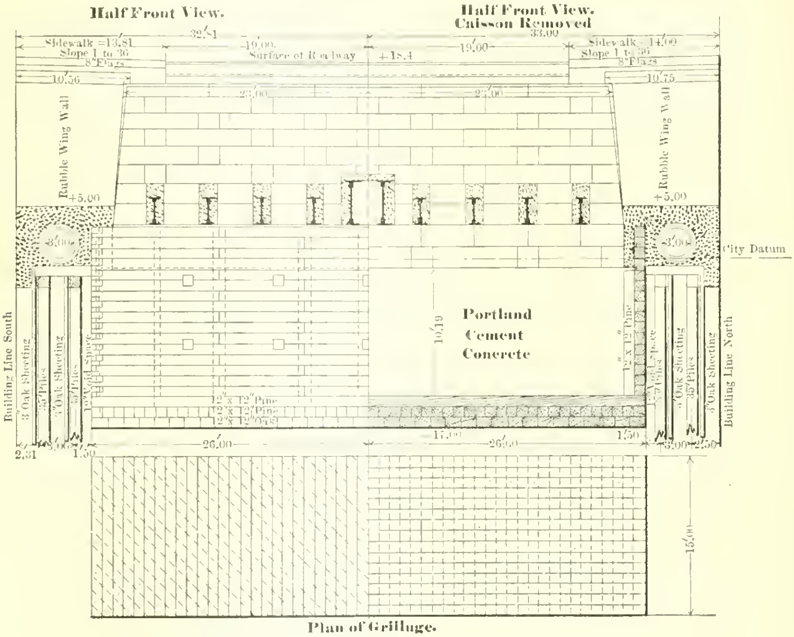


Fig. 8
West Abutment

This coffer-dam was then anchored back with three 2-inch anchor rods to piles driven about 50 feet to the rear. These anchors were to prevent the earth filling from forcing the coffer-dam towards the river when the excavating for the abutment was done. They proved only partially successful in this office. A sewer 5 feet in diameter emptied into the river on the center line of Van Buren Street. This sewer was divided into two sewers, each 3 feet in diameter, and passed around the ends of the abutment as shown in the illustration.

In Fig. 9 is given a front elevation of the west abutment, showing the pockets that receive the girders which form the floor for the west machinery room, previously mentioned.

In the plan of the west pier (Fig. 10) are shown the pockets formed to receive the tail girders when the bridge is open. Besides these pockets the pier contains two large chambers built in to save masonry. In one of these chambers a sump was made and in it placed a centrifugal pump driven by a small motor placed on the pier above. This pump is controlled from the operator's house and run whenever necessary to remove the water which leaks in through the concrete. In this plan



West Abutment Fig. 9

is also shown (by the broken lines) the location of the cast steel racks upon which the segmental girders revolve. The sections of the pier (Fig. 11) show the depth and form of the pockets mentioned above. In these sections is also shown the anchorage for the tail girders, which will be referred to again.

The east pier and abutment, although completed as one piece of masonry, were constructed separately. The abutment and east half of the pier, as originally designed, came between two seven-story buildings, with foundations extending into the street. The excavation for the pier

Half Front Elevation of Pier. Half Front Elevation, Caisson Removed.

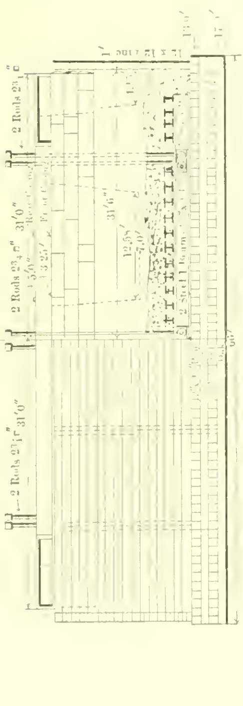
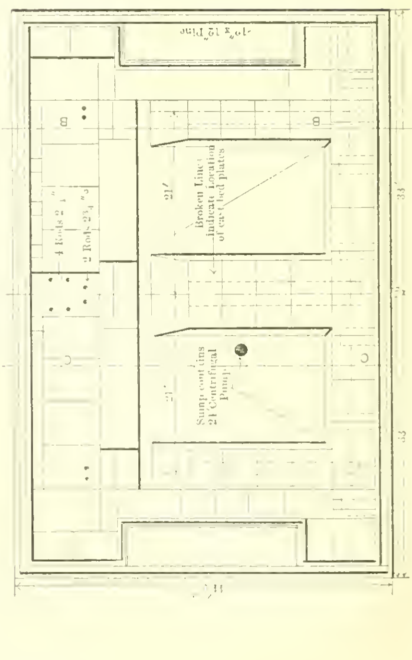
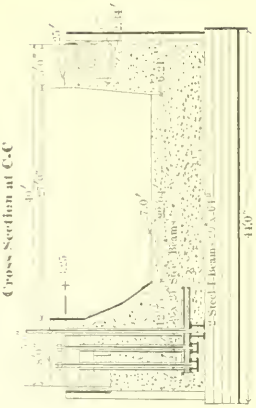


Fig. 10. West Pier.
Plan of Pier.



Cross Section at B-B

Fig. 11. West Pier.
Cross Section at C-C



came considerably below these foundations. This being the case the contractor preferred to reduce the width of the pier, which was to be sunk with an open caisson, and increase the width of the abutment, which was to be put in by a coffer-dam. Therefore the piling for the coffer-dam, shown in the section of the abutment (Fig. 12) was moved west about 18 feet or a little beyond the west face of the buildings.

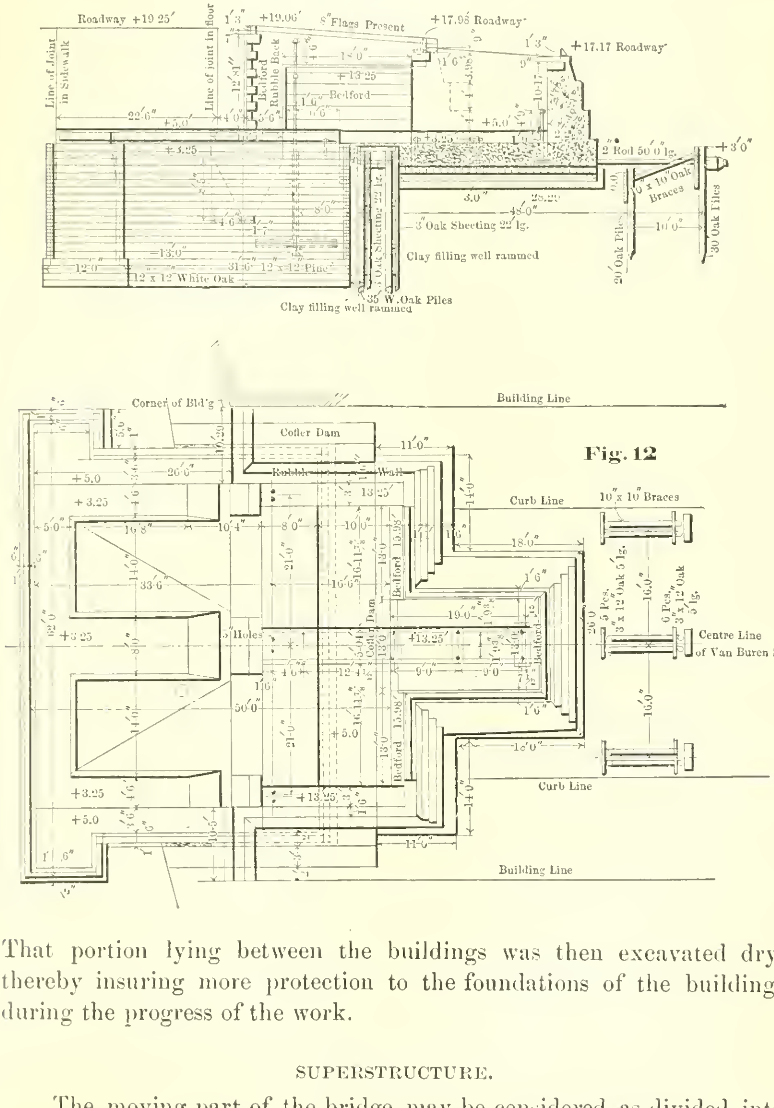


Fig. 12

That portion lying between the buildings was then excavated dry, thereby insuring more protection to the foundations of the buildings during the progress of the work.

SUPERSTRUCTURE.

The moving part of the bridge may be considered as divided into

three spans: the river span and two anchor spans. The river span, which has the appearance of a low arch (See Fig. 13), is composed of two cantilever arms, there being no bearing at the center between the two parts of each truss. The clear headroom above the water for the four middle panels is about 16 feet. The river span is 115 feet center to center of bearings. The anchor spans are each 30 feet 6 inches center to center of columns, and consist of two parts: the movable part from *A* to *Y* (Fig. 13), and the fixed part from *Y* to *G*. These two parts are held firmly together at *Y* by hangers passing beneath the tail girders.

Within these tail girders and between them, in the two end panels, are placed the counterweights for balancing the cantilever arms. These counterweights consist of cast iron; the total amount required for one side being about 129 tons. The exact amount of this counterweight was decided upon after the bridge was in operation. Sufficient weight was added to prevent the bridge from coming to a horizontal position when freely lowered by the brakes. The bridge, when so lowered, comes to a rest a little above the horizontal; the power is then applied and the motors force the bridge down to a level.

The floor on the draw consists of two courses of planking, each laid transversely to the length of the bridge. On the roadways the lower course is of 3½-inch pine, each plank being held to the flanges of each I-beam by two 3½ inch by ⅜ inch railroad spikes, driven from below. The upper course on the roadway is of 3-inch oak plank and is thoroughly spiked to the lower course with 6-inch spikes. The lower course on the sidewalks is of white pine, dressed to 1¾-inch, securely spiked to the I-beams and wooden joists. The upper course is of 4-inch by 1½-inch dressed and matched Georgia pine, and extends through the trusses to the wheel guard.

A uniform quality of open-hearth steel was used throughout the work, in which the average phosphorous limit was .06 per cent. for "acid steel" and .025 for "basic steel." When tested in specimens, cut from the finished plates and shapes, of not less than ½ square inch in section, an ultimate strength of from 60,000 to 68,000 pounds per square inch was required, with an elastic limit of not less than one-half the ultimate strength, with an elongation of at least 26 per cent. in 8 inches, and a reduction at point of fracture of at least 50 per cent. It must also, when cold, bend flat upon itself without sign of fracture, and be capable of withstanding the usual punching and drifting tests.

In Fig. 14 is shown a quarter plan of the draw span. The sidewalk on the approach joins that of the draw at *S*, while the junction between the corresponding parts on the roadway is at *R*. When the bridge is raised the floor of the moving part of the roadway passes back of and beneath that on the approach, making it necessary to bring

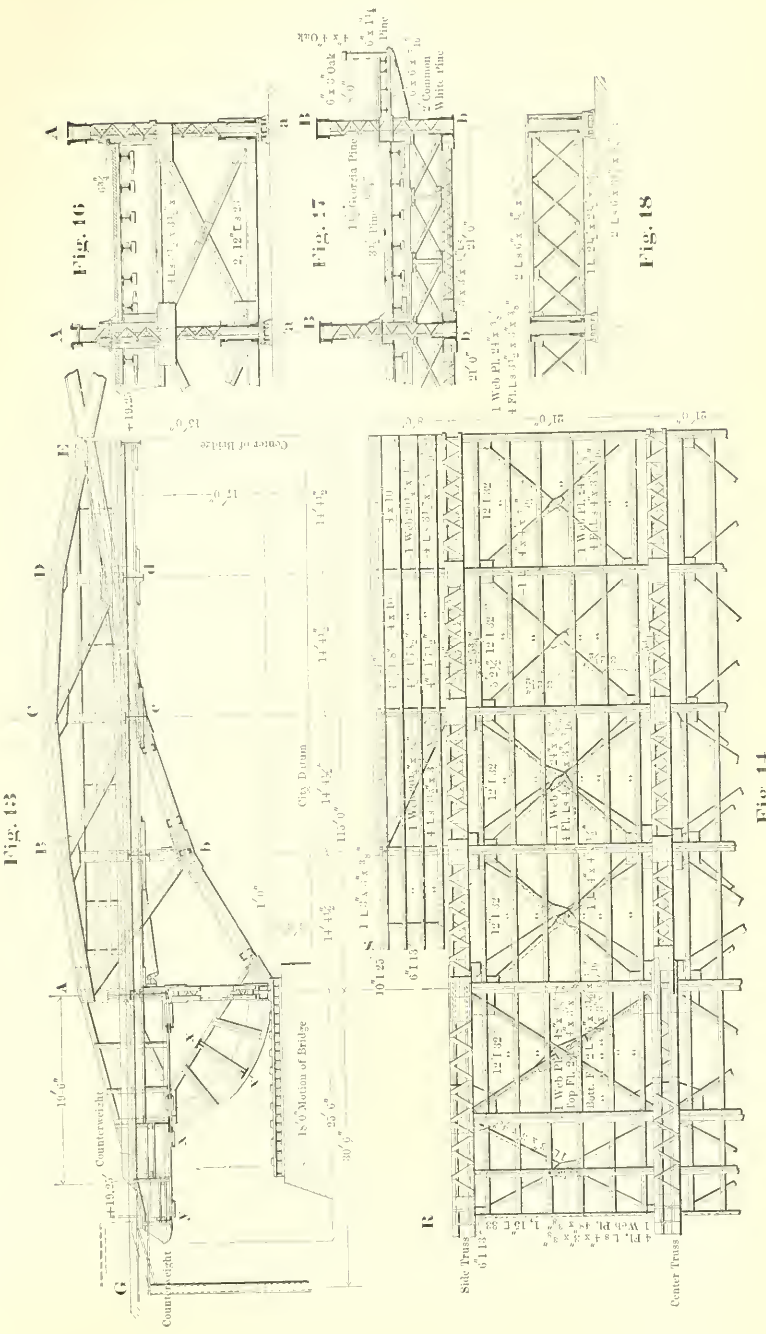


Fig. 13

Fig. 14

Fig. 16

Fig. 17

Fig. 18

the floor on the approach to a very thin edge to form a connection with the draw when the bridge is closed. The movement at the sidewalk is the reverse of the above; that is, the moving sidewalk passes above the fixed part when the bridge is raised. The method of making the connection between the floors of the moving and fixed parts is given in Fig. 15. In the castings for the roadway the part on the approach is brought out to a thin edge, while of those for the sidewalk the one on the draw is so drawn out. The movement at the sidewalk is more nearly horizontal than at the roadway, and it was necessary to make the connection on the sidewalk with a ½-inch steel plate for a distance of 12 inches. This difference of movement between the roadway and the side-

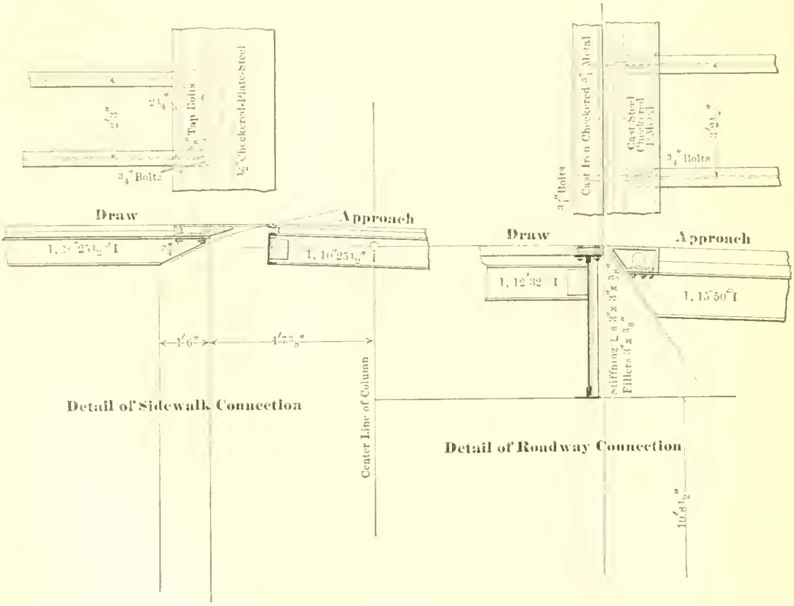


FIG. 15.

walk is due to the junction with the approach being made at points differing in relation to the center of motion, the junction for the sidewalk being in front of this center, and that for the roadway being behind it.

Figs. 16, 17 and 18 are sections at *A–a*, *B–b* and *X-x*¹ respectively and are given to show the bracing used at each place.

A detail of the tail girder, segmental girder and a part of the center truss is shown in Fig. 19. These girders are the same for the outside trusses, except that the pin connection for the operating strut (shown at *A*) is omitted, and the material in the girders of the outside trusses is

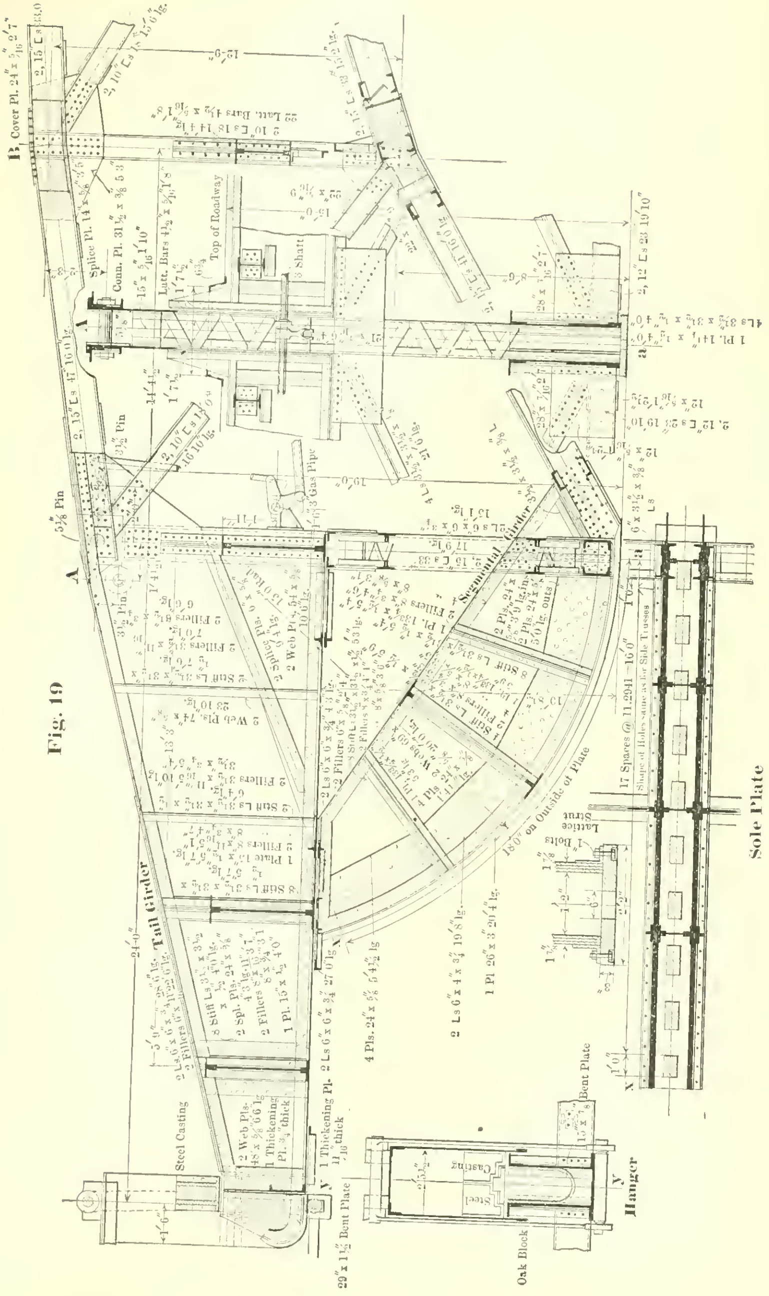

Tail Girder
Segmental Girder
Sole Plate
Hanger
Steel Casting
Oak Block
Top of Roadway

Fig. 19

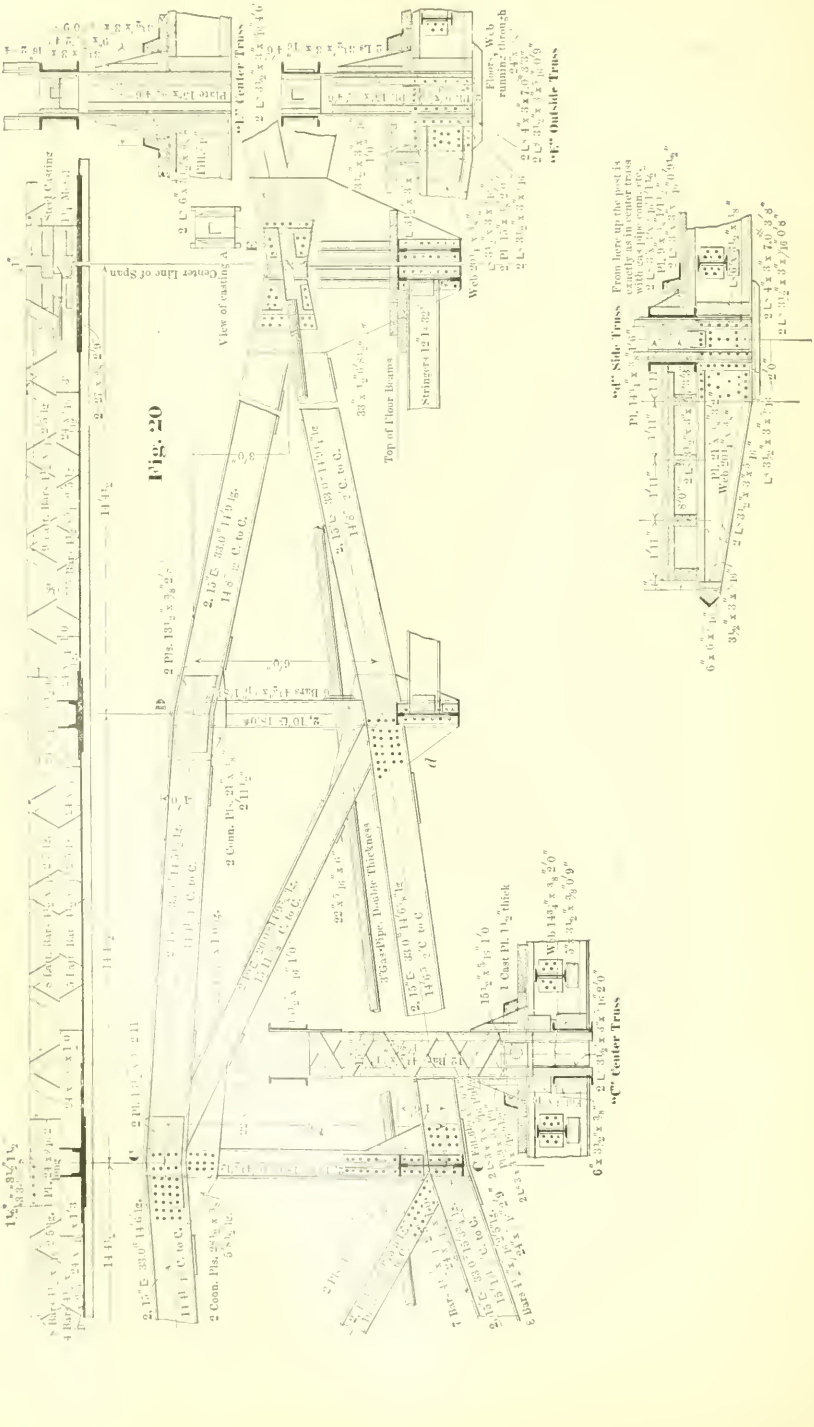

"C" Center Truss
"E" Outside Truss
"d" Side Truss
Center Line of Span
View of casting A
Top of Floor Beams
3" Gas Pipe. Double Thickness

Fig. 20

some lighter. On the bottom of the segmental girder is a steel track plate, 26 inches wide by 3 inches thick, and cut out, as shown in plan, so as to receive the teeth of the cast racks on the masonry, upon which these segmental girders revolve. This steel plate is securely bolted to the bottom flange of the segmental girder with one-inch bolts, in the manner shown in the section of the plate. At Y is shown the connection between the tail girder and the approach. When we have a sufficient load on the river span there is an upward pressure from this tail girder, which is received by the steel casting bolted into the end of the approach girder. With a load between A and the approach, the tail girder must be supported by the hanger at Y.

Fig. 20 gives the remaining portion of the truss and the center latch. The way in which the latch is operated is shown in Fig. 21. As stated before, there is no bearing at the center between the two parts of a truss. The only connection here is made by a pin latch, which is intended only to prevent lateral motion. This center latch is operated from the west side, and the locking apparatus is therefore omitted on the east side.

In Fig. 21 is given the method of applying the power to the bridge. From the machinery runs an operating strut joined to the center truss at A, as shown. Within this strut is a cast steel rack which engages with the rack wheel. In the position in which the strut is shown the bridge is closed and the latch at Y, and the pin latch at the center of the river span, are both in the position shown, and the bridge is locked, ready for traffic. When the bridge is open the cam at A has moved to the location indicated by the broken lines. In the first movement of the strut backward, the cam crank at A is revolved one quarter of a revolution, and acting on the cranks and levers shown, withdraws the pin latch at the center of the bridge. At the time this movement is taking place, a small roller strikes the cam on the rack wheel, and acting on the connecting levers, withdraws the tail girder latch at Y. These two duties performed, the bridge is free to move, and the succeeding movement of the operating strut begins to raise the bridge. These movements are simply reversed when the bridge is being closed and locked. The power to raise one-half the bridge is applied through one operating strut and carried to the two outside trusses by heavy bracing between them at panel point A.

The vertical adjusting, already referred to for bringing the two parts of a truss into the same plane, is shown in this illustration (Fig. 21). By increasing or decreasing the shims between the castings on the end of the tail girder and that on the approach girder, the center end of the truss could be raised or lowered.

The two approaches being of a similar construction, the west one

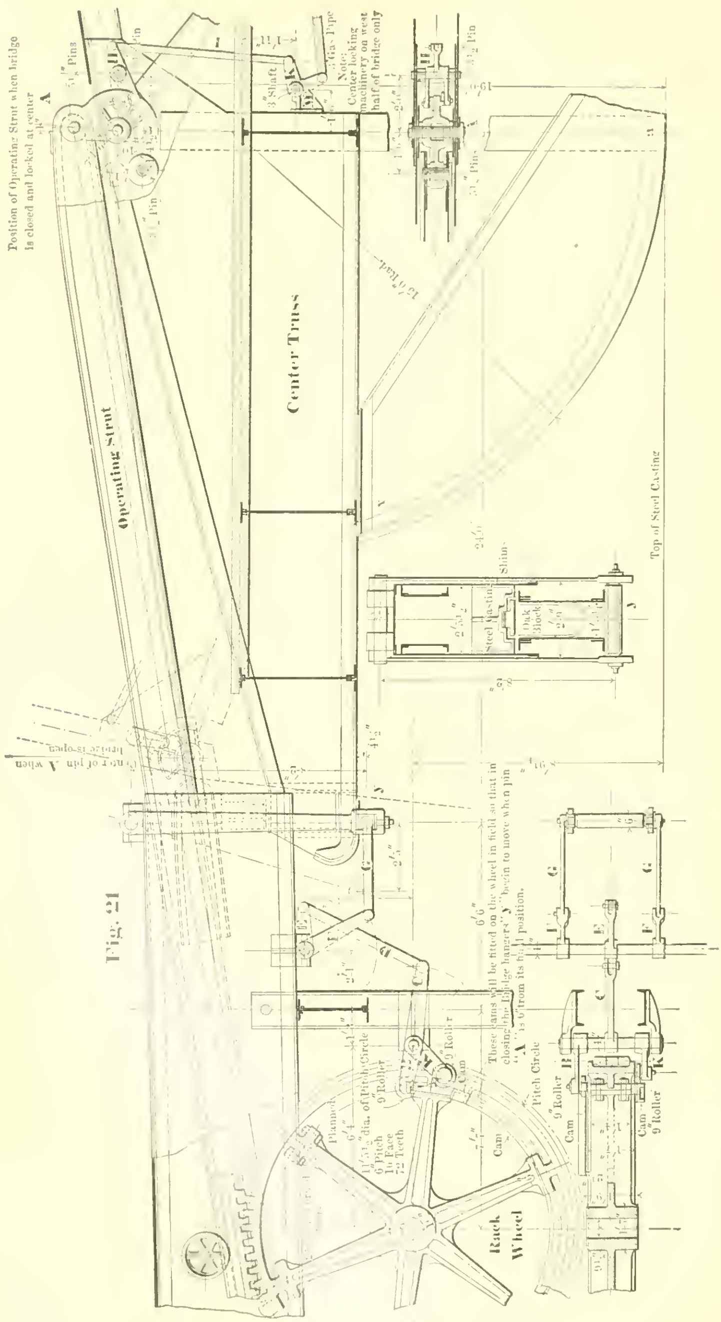

Operating Strut
Center Truss
Rack Wheel
Top of Steel Casting
Position of Operating Strut when bridge is closed and locked at center
Center of pin A when bridge is open
Note: Center locking machinery on west half of bridge only

Fig. 21

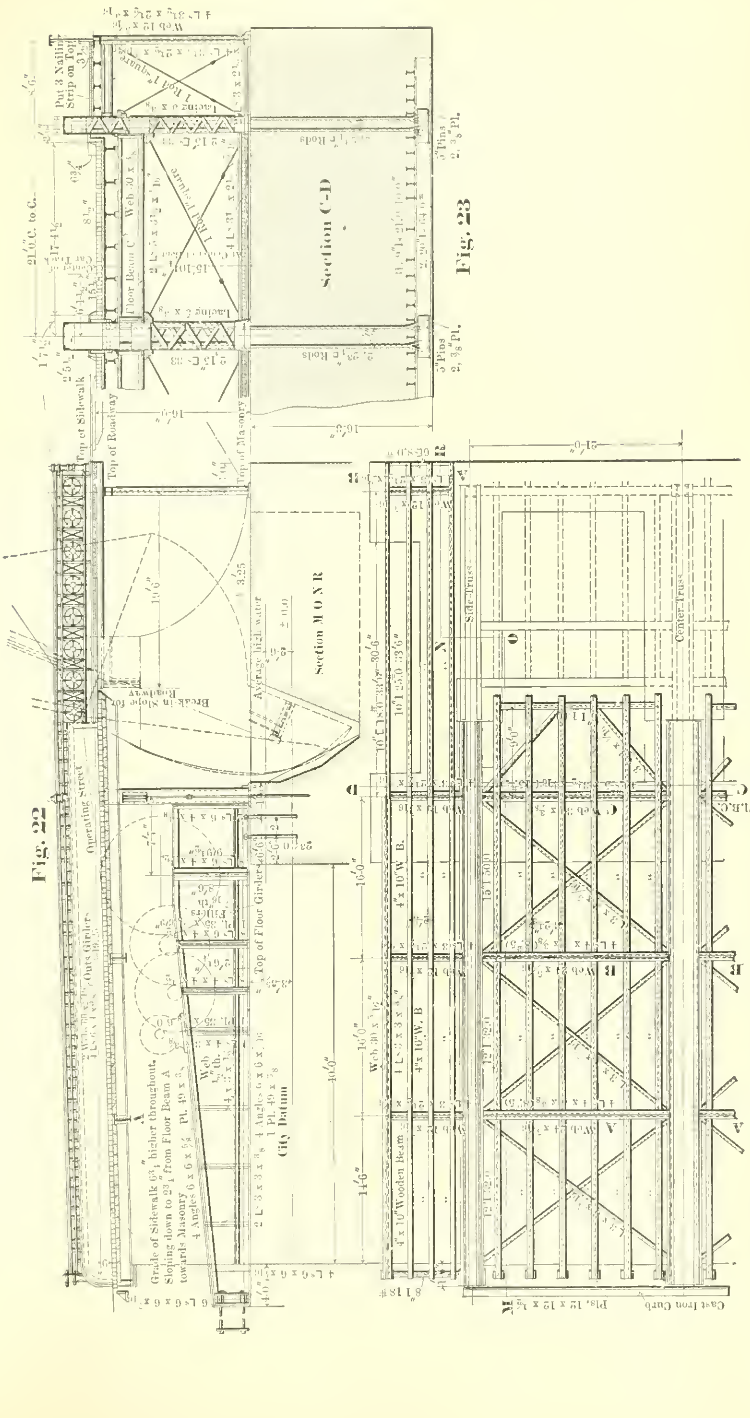


Fig. 22

Fig. 23

only is illustrated (Fig. 22). In the longitudinal section is shown the machinery girder, with the position of the motors and machinery indicated. This machinery girder is a very heavy box girder, 4 feet wide and $8\frac{1}{2}$ feet deep at the pier end. Besides carrying the vertical loads of the motors and machinery, it receives the longitudinal thrust brought to the machinery by the operating strut. To resist this thrust, the girder is anchored at the west end by four $1\frac{3}{4}$-inch rods passing entirely through the abutment, and at the east end by four $2\frac{3}{4}$-inch rods reaching to the bottom of the pier.

In the half cross-section through the approach (Fig. 23), is shown the anchorage for the approach girders, which act as anchors for the river span. This anchorage was placed directly upon the grillage foundation of the pier.

MOTORS AND MACHINERY.

In Fig. 24 is given a plan and elevation of the machinery for one-half the draw. The power being applied by the motors to shaft No. 1, is passed through the train of wheels to the operating strut at X. Of this machinery, all the gear-wheels are of cast steel, excepting the arms and hub of the rack-wheel. In this latter wheel, the power is applied on the rim and carried by the rim to the operating strut, for which reason the center was made of cast iron. The rim was cast in one piece, and not in sections as shown. Each of the other gears was cast in a single piece. The large wheels on shaft No. 2 were made with eight arms instead of six, as shown. On the middle of shaft No. 2 a brake-wheel was added, which is not here shown. This wheel is 5 feet in diameter, and has an 18-inch face. An 18-inch steel band brake is operated on it by compressed air. This brake is intended to be used only in case of an accident to the other brakes. The automatic brakes shown on shaft No. 1 were placed outside of the gears to make room for the motors, which are both on one shaft. These changes and some further additions are clearly shown in Fig. 25, which is produced from a photograph, taken after the work was completed.

The original specification for all cast steel was as follows: Ultimate strength of at least 70,000 pounds per square inch; elastic limit at least 40,000 pounds per square inch; an elongation, in 8 inches, of at least 25 per cent., and a reduction at point of fracture of at least 40 per cent. All sample bars, from which test specimens are made, to be at least $2\frac{1}{2}$ inches square, and to be annealed with the castings which they represent. So much difficulty was experienced in obtaining steel of this quality in *any* of the large castings required, that the specification was changed to the following: Ultimate strength of not less than 65,000 pounds per square inch, and elastic limit of at least 32,000 pounds;

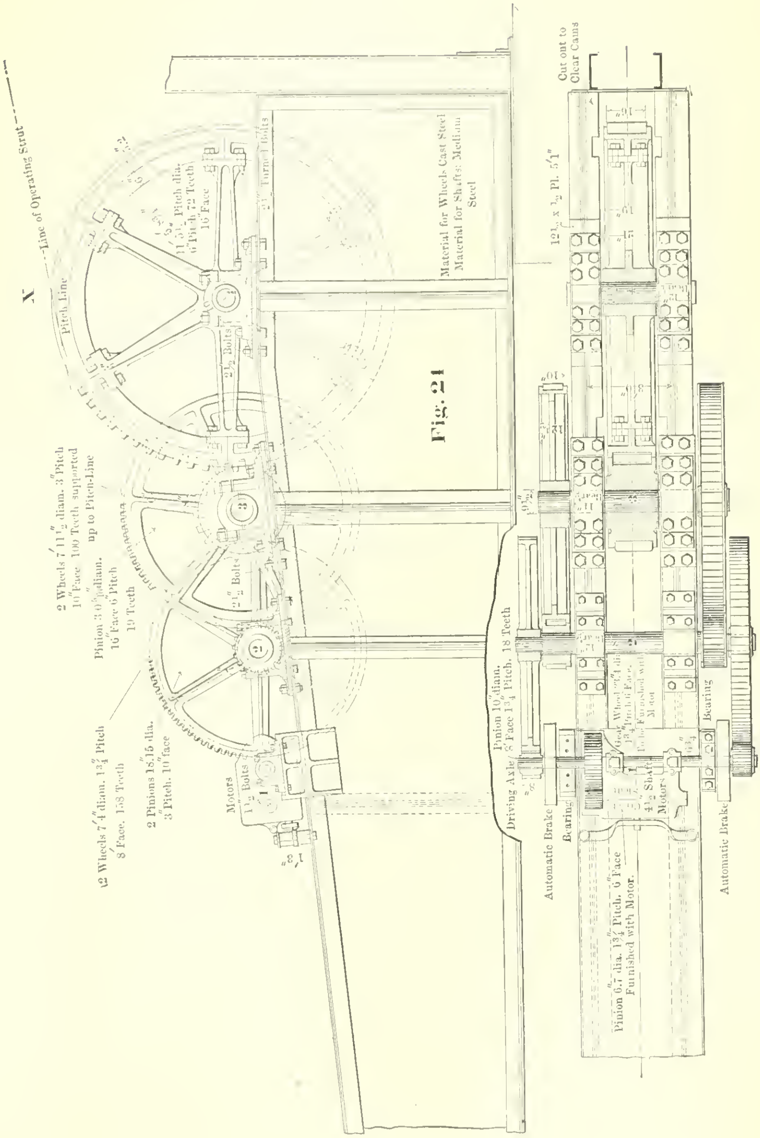

Line of Operating Strut
Pitch Line
Material for Wheels Cast Steel
Material for Shafts: Medium Steel
Cut out to Clear Cams
Motors
Bearing
Automatic Brake
Bearing
Automatic Brake
Furnished with Motor.

Fig. 21

elongation, in 8 inches, at least 20 per cent., and reduction at point of fracture of at least 25 per cent. This specification was filled only after rejecting many of the larger castings once, and some even twice, and the rim of the rack-wheel was accepted with an elongation considerably below this specification.

There are two 50 horse-power railway type, series wound, Westinghouse motors for each half of the draw, which are governed by a series multiple controller and connected to operate separately or in unison.

The automatic brakes are 30 inches in diameter with a 6-inch face, and are operated by compressed air. If at any time during the opening or closing of the bridge, the current is cut off, these brakes are automatically applied, and remain on until released by the operator. The air for use on these brakes and for operating the gates and signals is compressed by a compressor operated by an eccentric placed on the end of the motor shaft. This arrangement makes the compressing of the air also automatic. A pressure of about 35 pounds is used, a valve on the pump releasing the air above a pressure of about 40 pounds, although the compressor continues to work while the motors are in operation. The air, for use on both sides of the river, is compressed on the west side; that to be used on the east side being piped across, beneath the river, and stored in a reservoir. With the exception of the air compressor the machinery on the east side is a duplicate of that shown for the west side.

The bridge is provided with two gates, of the ordinary railroad type, one of which is placed on the right-hand sidewalk of each approach. When closed, each gate stops the traffic on the right-hand roadway, thereby enabling the operator to quickly clear the bridge of traffic and make it ready for opening. When once open, the bridge itself forms a very effective gate both for the roadway and sidewalks. Each operator controls the gate on his side of the river. The signals, which are at the center of the span, are operated from the west side.

In addition to the electric equipment already mentioned, each operator's house is provided with an electric heater, an electric bell and push-button, by which, with a code of signals, the operators may communicate quickly, and also with a special telephone for use in case of any accident when the bridge is open, at which time it may be necessary to communicate some message not provided for in the code. Everything has been added to the bridge which was considered necessary to insure the safety and reliability of its operation.

The power for running the bridge is a 500 volt current brought from the Chicago Edison Company's Washington Street power station.

From quite a large number of tests made on the current at different times and with the wind from various directions, it has been found

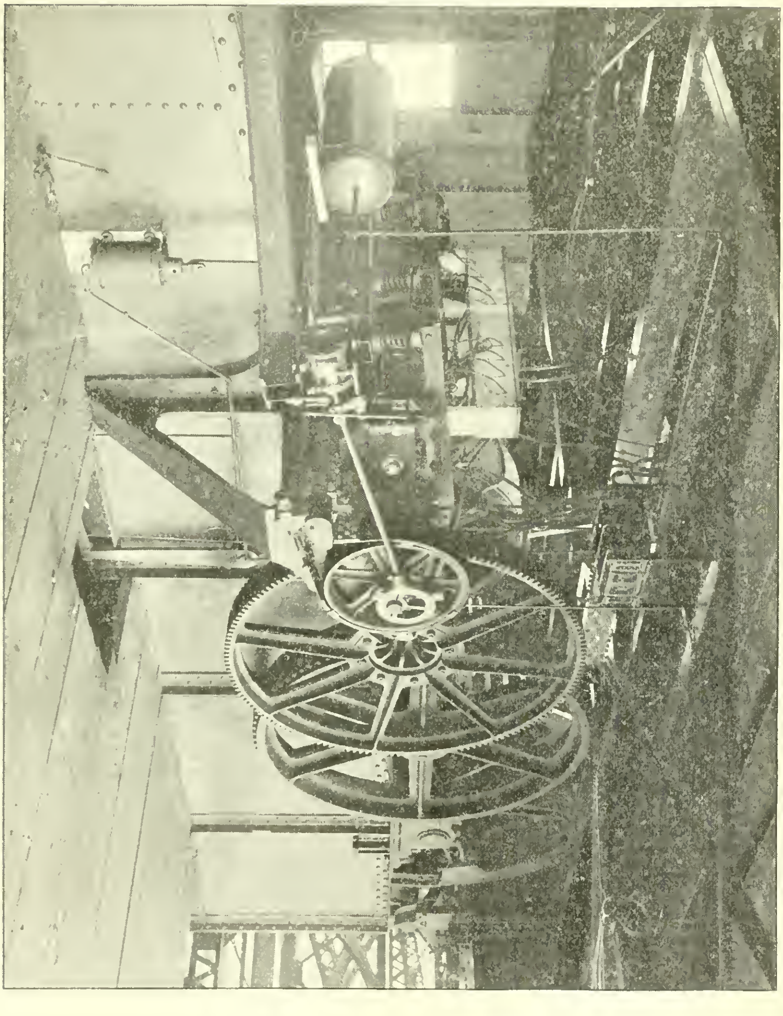


Fig. 25.

that the average horse-power required to open one side of the bridge at a time is about 60, and that required to open both sides at the same time about 96. However, none of the tests were made at a time when the wind was higher than what would be termed brisk. It was observed that a moderate, or even brisk wind, blowing from one side, offered more resistance to the operation of the bridge than one of the same velocity blowing in the direction of the street. This was due, no doubt, to friction that a side wind caused between the racks on the segmental girders and those on the masonry. It is not believed that this resistance from a side wind would exceed that from a direct wind of the same velocity for winds higher than those observed.

CONSTRUCTION AND COST.

The bridge was designed and patented by the late William Scherzer, who died about the time the drawings were completed. That the work performed by him had been *very* carefully and thoughtfully done is shown by the closeness with which his design has been followed by those who have carried his work to a successful completion.

Work was begun on the substructure early in 1894, and the bridge was completed and opened for traffic on February 4, 1895. Since this date it has been operated very satisfactorily. The time required for opening it is about one-half that for opening a steam-power swing bridge.

In comparison with a swing bridge, giving the same clear channel, the cost of this bridge seems somewhat high. This may be partly accounted for by the fact that this bridge is of a new design. Contractors do not bid so reasonably on such a design as on work with which they are familiar. Neither can the work be done for the same unit price on a bridge of new design as one of a familiar design. Moreover, the substructure of this bridge was more expensive than it would ordinarily be, even for a bridge of the same type. This was due to the difficulty in putting in some of the foundations.

The total cost of the bridge, including the approaches, electric equipment and cables to the power house, was $163,850.00.

The substructure for the bridge was built by the Fitz Simons & Connell Co., of this city. The contract was awarded them at unit prices for each kind of material entering into the work, and not for a lump sum. This method added very much to the responsibility and work of the engineers in charge for the city. Mr. W. R. Kellogg, a member of this society, had charge of the field work on the bridge, throughout its construction. Much of the credit for the manner in which the parts of the superstructure came together, is due to the accuracy with which Mr. Kellogg located the substructure. Some parts of the substructure, as

already shown by the illustrations, were of an especially difficult construction, and much credit is due to the contractors for this work, for the manner in which it was performed.

The contract for the superstructure was originally awarded to A. Gottlieb & Co., but Mr. Gottlieb's death soon afterward made it necessary to re-let the work, and it was given to Charles L. Strobel, a member of our society. Mr. Strobel sub-let the manufacturing of the iron work to the Elmira Bridge Co., of Elmira, N. Y., and the manufacturing of the machinery to the Scaife Foundry & Machine Co., of Pittsburg. Mr. Strobel and his able assistants, who made the shop plans for the bridge, deserve much credit for the care with which all the details of the bridge were worked out.

The electric equipment and air plant, including the brakes, air compressors, gates, signals, etc., were designed and furnished by G. P. Nichols & Bro., of Chicago. The former is also one of our members.

The bridge was constructed under the supervision of Mr. Samuel G. Artingstall, City Engineer, the author of this paper having direct charge of the work.

The following figures on the cost of this bridge as compared with certain other city drawbridges may be of interest:

Wells St. Swing Bridge:

Substructure	$59,000 00
Superstructure	86,700 00
Machinery and engines . . .	4,700 00
	$150,400 00

This bridge has two roadways of 21 feet each center to center trusses and two sidewalks of 8 feet each, is 220 feet long, and gives two clear channels of about 72 feet each.

South Halsted St. Lift Bridge:

Substructure	$84,700 00
Superstructure	81,400 00
Machinery and engines . . .	50,000 00
	$216,100 00

This bridge has one roadway of 40 feet center to center trusses and two sidewalks of 9 feet 4 inches each. It is 130 feet long center to center bearings and gives one clear channel of 118 feet.

Van Buren St. Rolling Lift Bridge:

Substructure	$79,600 00
Superstructure	73,100 00
Electric equipment	11,150 00
	$163,850 00

This bridge has two roadways of 21 feet each center to center trusses and two sidewalks of 8 feet 6 inches each. The channel span is 115 feet long center to center bearings, and gives a clear channel 109 feet (between masonry abutments).

N. B.—The engineering and inspection expenses are not included in any of the above costs.

DISCUSSION.

A VIEW of the Tower Bridge in London, England, taken at the time of its inauguration and presented to the society by Mr. Liljencrantz was then shown and Mr. Strobel furnished the following data:

The first caisson was begun in September, 1886. Both piers were completed in January, 1889. The formal opening of the bridge took place June 30, 1894. The steel work was furnished by Sir William Arrol & Co.; the contract price was $1,685,000. The piers and abutments, John Jackson's contract, cost $656,000. The hydraulic machinery, Armstrong & Co.'s contract, cost $426,000. The masonry superstructure cost $745,000. Other contracts, $636,000, making a total of all original contracts, not including outside expenses, nor engineering, of $4,150,000. The opening span is 200 feet, which is twice the opening in Van Buren Street bridge. The weight of each leaf is about 1,000 tons gross; the pressure in the accumulators is 850 pounds per square inch. The test load of 150 tons on the end of each leaf gave a deflection of $1\frac{5}{8}$ inches.

THE PRESIDENT:—The account of the tower bridge is certainly very interesting; in fact, the explanation of its cost of over $4,000,000 as compared with $160,000, seemed desirable, as the architectural effect is rather elaborate.

MR. BUSH:—I will say that Mr. W. W. Curtis, who represents the Pittsburg Bridge Company in this city, had expected to take part in this discussion to-night, but as he was unable to be present, has asked me to read for him a few notes prepared by him.

The following paper was then read by Mr. Bush:

MR. CURTIS:—Mr. Roberts has very kindly given me an opportunity to look over his paper, and present such discussion as I might desire, especially with reference to the comparative merits of the Van Buren Street bridge and the Halsted Street bridge, with which I was directly connected.

The society is indebted to Mr. Roberts for the very complete manner in which he has described this piece of work. This city seems to be especially selected as a trying ground for new schemes in the way of

bridge construction. Draw spans have been worked out here to somewhere near the limit of perfection so far as their efficiency in the line of public service is concerned, and unquestionably the same care and freedom in expenditure in first cost will insure a corresponding development in whatever type of bridge may be found best suited to the local conditions. Of the three different types of bridges built since it was found necessary to substitute something for drawbridges, one represented the extremely cheap, the second the extremely costly, while the third is somewhere near the golden mean, so far as cost alone is concerned. Fortunately the city in its experimenting has not been called upon to pay the cost of any absolute failure, all of their bridges being successes to a greater or less degree.

In comparing the Halsted Street and the Van Buren Street bridges there are several points which should be borne in mind to do justice to the former. It was a much more radical departure from existing structures than the Van Buren Street bridge, and the conditions under which it was built were very different. Plans for the latter work had been made by Mr. Scherzer and very cordially adopted by the Engineering Department of the city. The contracts called simply for the proper execution of the work according to the plans and specifications of the City Engineer, and the contractor was responsible in no way for the design or the successful operation of the structure, excepting in so far as that might be affected by poor work on his part. On the other hand the Halsted Street bridge was never looked upon with any favor by the city; its failure was predicted time and again, and while I very willingly recognize the fact that the City Engineer and his assistants endeavored to treat the contractors with perfect fairness regardless of their opinions of the wisdom of the expenditure of money entailed by the contract, the contractor was nevertheless compelled to assume risks on the enterprise to an unreasonable degree, and there was not the same interest taken in the bridge as in the Van Buren Street structure. The contractor was compelled not only to give the usual bond, guaranteeing the proper execution of his contract, but was also required to file a special bond for $50,000, guaranteeing the correctness and the sufficiency of the engineer's plans for the entire structure, the $50,000 to be forfeited in case the bridge was not made a perfect success. It seems now of course that such a bond was a mere formality, but at the time this work was constructed there were several questions which could not be determined in any way except by actual tests, and which, if such tests had not resulted favorably, would have caused a more or less complete failure of the whole enterprise, or would have entailed very heavy additional expense to have insured its success. Under these circumstances it is not surprising the cost figured for the machinery was large; or that in

the actual construction a large amount of money was spent in precautionary measures, which we now see could have been saved.

Examining the statement of the cost of the Halsted Street bridge as given by Mr. Roberts, we find it divided as follows:

Substructure	$84,700 00
Superstructure	81,400 00
Machinery and engines . . .	50,000 00
Or a total of . . .	$216,100 00

Of the item of substructure, $34,000 alone was required for the pneumatic caissons, the balance covering the cost of removing the old pile work in the river, a large amount of dredging, the masonry in the four main piers and two small piers, together with the retaining walls and engine-room foundation, with the various piles and timber required therefor. The item of engines and machinery covers a complete steam plant in duplicate, consisting of two boilers and two engines, with the necessary gearing and shafting, besides the counterweights, cables and their necessary connections and supports. In the construction of a similar bridge the expensive engine room beneath the street, as well as the steam plant, would be eliminated entirely, resulting in a considerable saving in first cost as well as a very large saving in cost of operation, which is now the worst feature of the Halsted Street bridge. By placing the power house in one of the towers above the roadway and using electric power furnished from a central station, the number of attendants required as well as the cost of power would be no greater in the case of a lift bridge than for the Van Buren Street bridge. It may be said that the two pieces of work should be compared as they stand, not as they may be modified in the future designs; but this is hardly a fair way of looking at it, because of the much greater novelty of the Halsted Street design, and the fact that the power was generated on the work itself instead of being purchased as at Van Buren Street, thus adding to the first cost of the power plant. There is another item also to be considered, viz.: the difference in the cost of material at the time the two pieces of work were contracted for. By referring to my estimate book I find the difference in the market price of angles amounted to $13.00 per ton, which, on the weight of the Halsted Street bridge, represents about $9,500.00. Mr. Waddell, the designer of this bridge, has placed himself on record in the *Transactions of the American Society*, as believing this bridge could be duplicated, with such modifications as I have suggested above, for $50,000 less than it actually cost. While I think the gentleman is possibly a little too sanguine in this, I am confident $175,000 at the present time would be sufficient to cover the expense of such a construction.

The main objection raised by engineers to a bridge of the type of the Halstead Street bridge, has been based upon the apparent absurdity of moving such a heavy mass to the height necessary in order to open the channel. On the face of it, it certainly seems that there should be some method requiring a less expenditure of energy to secure this result, and it is interesting to compare the actual power required in the two structures under consideration. Tests made at Halsted Street for Mr. Artingstall by Mr. Frederick Sargent, indicate that with both engines working at a high speed and opening the bridge in the shortest possible time, 115 indicated horse-power was required, while operating as in actual practice, with one engine alone, and at a speed 20 per cent. less, the power developed was 96 indicated horse-power. The power furnished for this work consists of two engines of a nominal rating of 60 horse-power each, with steam at 80 pounds pressure. Mr. Roberts states the indicated horse-power required for the Van Buren Street bridge, to be 96 horse-power, which may be reduced possibly by more accurate counterbalancing. He states, there are two 50 horse-power motors supplied for each half of the draw, or 200 horse-power supplied for the bridge, as against 120 horse-power at Halsted Street. You will also notice the clear opening in the Van Buren bridge is 10 per cent. less than at Halsted Street. The speed for opening the two structures apparently is not very different, either being sufficiently rapid for any conditions.

The only doubt I have ever entertained as to the value of the rolling bascule bridge has been based upon the possible effect of a collision. This was one objection raised to Halsted Street bridge, but that structure has passed through three collisions with credit to itself and injury to the boat. What the result would be if it were struck by the bow of one of the heavy lake steamers there may possibly be room for doubt, but I believe the probability of serious injury from collisions is exceedingly small. With the bascule bridge of whatever type, I think such a collision as one already experienced at the other bridge would result in the demoralization of the bridge and its being thrown out of service for some days at least; and such collisions are extremely probable. It is to be hoped experience will prove the Van Buren Street bridge has greater resisting power as against such accidents than the writer believes it possesses. I lelieve the direct lift bridges have a province of their own and that therein they are superior to any other structure, and I shall certainly rejoice if Mr. Scherzer's last work remains as successful as it is to-day.

Mr. Goldmark.—Mr. Roberts, in this very interesting and excellent paper, has given perhaps the fullest account of any of the newer bridges that we have in Chicago. The drawbridges, as he very truly remarked, have reached a high state of perfection. They are certainly efficient, but there are many reasons why the drawbridge is not well

adapted to a narrow river of this kind, where the value of real estate and of dock room is extremely great. The Van Buren Street bridge—I think everybody who saw it operate the other day will agree—seems to be an extremely satisfactory and efficient machine or tool for doing the particular work which it has to do, that is, to carry a heavy roadway traffic at a moderate height above the river, and at the same time give a clear opening of 100 feet for vessels. The height above the river there is limited, and consequently there is considerable difficulty in finding room for the counterweights, as it moves downward. In fact, even in Van Buren Street there are large excavations in the concrete, and a possible influx of water will have to be taken care of, and still the Van Buren Street and our other Chicago bridges down town are not extremely close to the water. There is considerable height, I think twenty-four feet, from water to roadway. In many cases, in Chicago and in other cities, this distance from roadway to water is much less, and a bridge which is counterweighted by a tail end in that way presents certain difficulties.

Another thing in connection with this bridge that strikes me is that the 100 feet clearance, which is provided here, is probably somewhere near the limit to which a bridge of this kind can be economically built. I think that whatever may be said of the direct lift bridge, such as is used at Halsted Street, it certainly can be used for considerably greater lengths. For lengths of 200 feet it would find a more useful field for application than it did find here, because the difficulties of building such a bridge would probably not increase so much as in the case of a cantilever, in which the deflections increase very rapidly with the space overhung.

Mr. Curtis has given a very interesting explanation of the Halsted Street bridge, and I really got up to say a word or two about the other bridge that Mr. Curtis referred to, which was the cheap bridge of the three novel types. Some three years ago, when I entered tho employ of Messrs. Shailer & Schniglau, they had taken the contract for the Canal Street bridge for a total contract price for superstructure, substructure and machinery, including the iron approaches, of $40,000. This bridge was to have a clear span of 80 feet, and the approaches made the total length, if I remember rightly, in the neighborhood of 175 feet. The roadway was to be 20 feet wide, with two sidewalks, 5½ or 6 feet each. The iron work of the approaches had been designed in two separate short spans on each side. They were afterwards changed to single plate girders. The general outline of the bridge had been detailed by Mr. Kandeler sufficiently to make his bid and estimate. The bridge was taken up in the office and worked out with some care, and I want to say that I know from experience that any bridge of this kind

involves an infinite amount of patience and of work in order to make it go together at all, and I realize that the gentlemen who have had to do with the Van Buren Street bridge must have had a great deal of patience and a great deal of skill to get such a perfect structure.

For the Canal Street bridge I will say that, although it was designed for a rolling load of 100 pounds to the square foot, the strains in no part of the structure are at all heavy. The bridge fulfills its purpose perfectly, and carries the heavy teaming traffic of the lumber district with safety and without any excess of deflection where the two ends meet, though they are not locked in any way. The substructure was built somewhat in the way the Van Buren Street bridge was, that is, it consists of piles cut off 16 feet below low water, with concrete and stone piers above, the four small piers being independent, and the abutments being built in a similar way. The machinery is independent, and includes two double cylinder engines in each of the little houses on each approach, with a place for coal. In comparison with other bridges, I think the contract price is perhaps quite an interesting item. For more money we could, of course, have built a heavier bridge, and perhaps a more ornamental bridge, but I think that the Harmon patent on which this bridge was built is really a very economical style. There is no place in which the strains, either in tension or compression, are large. All the girders or beams are reduced to small sizes, and the load is carried very directly to the towers and to the piers, and when there is a cantilever action, it is taken care of by a tower about 40 feet high. Of course that is a very economical way of taking care of a cantilever, rather than by the comparatively shallow girders such as are used at Van Buren Street. It does not look as well, I admit, but it is certainly more economical, and I think it explains in a considerable measure the difference in cost between these two bridges.

Mr. Hasbrouk.—I would ask for what reason the Van Buren Street bridge was made of two independent cantilevers, rath· · than an arch, as the Metropolitan is.

Mr. Strobel.—I would say that in case of the Van Buren Street bridge, there is no particular advantage to be gained from treating the bridge as an arch. In the case of a longer span I should consider there would be an advantage in arranging to have the two parts meet in the center and act as an arch. The thrust on an abutment of a Chicago river bridge is never a desirable feature, as the soil is very yielding.

Furthermore, there is a wedge action which might take place if the bridge acted as an arch, which would make the opening of the structure harder and would require more power.

I may add, as it may not have been explained as fully in the paper as might be, that this bridge could have been balanced perfectly. The center of gravity could have been arranged to coincide with the center of the segmental girders. In that case the balance would have been complete in every position of the bridge. It was preferred, however, to arrange the balance so that there would be a tendency for the bridge to open as soon as it was unlocked. Then, in lowering the bridge, the position of the center of gravity is such that the bridge will drop a part of the way. After it has reached pretty nearly a horizontal position, the bridge has to be forced down to a complete horizontal position.

Mr. Hasbrouk.—The question raised in my mind was in regard to the deflection—whether or no it is wise, or otherwise, to make two cantilevers. We have two cantilevers, it strikes me, that having one arm loaded, the deflection of that arm might be considerable, and the other arm not being loaded might make a break in the bridge at the center.

Mr. Roberts.—For the loads that we have here in the city there is no deflection. As yet, we have had nothing heavier than a six horse team with a very heavy load go over the bridge. I was on the bridge the other day when a six-horse team crossed it, and there was no such deflection. The castings at the center through which the 3-inch steel pins work are very heavy; and, I think, are entirely capable of taking up even greater loads than we will have on this bridge. How it would be on a railway bridge, as the Metropolitan, where they have a heavy motor-car, I cannot say.

Replying to the question that was suggested by Mr. Goldmark, he thinks that we have very nearly reached the limit of span for which this type of bridge is adapted. I would say that I think not, so long as we can have a little more head-room. We only have about 15 feet from the bottom of the track to the center of motion. Where the approaches could be made longer and the bridge made higher, there is no reason why the span could not be made materially longer.

Mr. Bush.—Assuming a pressure of 18 pounds per square foot strikes me as being considerably lighter than ordinary specifications.

The President.—Mr. Roberts is called upon for too much in the way of explanation, and hence I will presume to answer Mr. Bush with the suggestion, that with a pressure of 18 pounds per square foot from wind it is quite safe to assume that there will be no navigation on the river, hence no occasion to expose the draw.

Mr. Appleton.—The description of this novel structure is certainly very interesting. There are a few points about the operating machinery on which I would like a little more information. As I

understand it, the brakes on the small wheel, as well as on the large wheel, are operated by compressed air, and that there is but one air pump. It would seem desirable to have some form of hand brake for use in case of failure of the compressed air through leakage or breakage of pipes.

This bridge is operated by electric motors. The current comes from a distant station operated by a private corporation. If the current should fail at any time, what would become of the bridge? Would it not be well to have a duplicate line of cables to supply the electric current? And would it not be well to have some kind of hand gear for use in emergencies? And, asking for information merely, what are the advantages of electric motors in this case over steam engines?

THE PRESIDENT.—Mr. Roberts has been called on so often to answer questions. I think I will call on Mr. Nichols.

MR. NICHOLS.—As I was acting in the capacity of contractor, placing the motors there was a matter of course. There certainly are advantages in the use of electric motors. The combined capacity of the two motors is 150 horse-power. You can imagine how much room a steam plant that will generate that amount of power would take up, with all the boilers and the stack and everything pertaining thereto. It would necessarily be duplicated on the other side, which would be practically an impossibility, although I suppose it might be done some way.

As to the comparative cost of operation by steam and electricity, that is purely a matter of arrangement between the city and the parties furnishing the current. It is true that in the transmission of power by electricity there is a loss of about 25 per cent. between the generating point and the point of application, but that is more than offset by the fact that so much less space is required.

As far as the danger of the current failing is concerned, it is hard to conceive of a more perfect or more reliable system. With such an engine and steam plant as is usually placed on a bridge, the conditions are necessarily unfavorable for efficient service. The source of power, or generating plant, is at the Chicago Edison Company's station, at the corner of Market and Washington Streets, where they have compound engines of large units and in duplicate, and the same with the boilers and generators, so that if anything should happen to any part of the plant, a duplicate part could be substituted. The building is practically fireproof. Connection is made between the generators at the station and the motors on the bridge by heavy armored cables laid in iron conduits under ground. The diameter of the wire conductors is something like $\frac{3}{8}$ inch, and, with the insulation, is something over an inch, so it would be very hard to rupture the circuit by mechanical means. As far as

burning out is concerned, that is hardly possible, as the type of motor used is such as designed for street car and electric locomotive work, and is designed with reference to rough usage, excessive overloads and scarcely any attention; so, comparing electricity with steam, the advantages are greatly in favor of the motor. For comparison we can refer to the bridges that have previously been equipped with motors. At the Rush Street bridge there was less trouble than with the new Madison Street bridge, which was started about the same time. There were several stoppages with the steam bridge, while with the electric, none at all. Similar results were obtained in Milwaukee. At the time the Grand Avenue bridge was equipped with an electric motor, the Michigan Street bridge was equipped with steam. The City Engineer has no hesitation in saying there is no comparison between the operation of the two; the steam bridge caused them some trouble, the electric none.

Why no provision was made for hand power is for Mr. Roberts to say, as that question did not come within the province of my work. While the air brakes have in every respect come up to our expectations and have proved themselves to be extremely reliable and easy of operation, and have not in a single case failed to act quickly and positively, it has been decided by the Bridge Engineer that it would be wise to provide supplementary brakes to be worked by hand, in case of emergency.

Mr. Johnston.—In regard to the remark that was made about the advantages of having one clear span, rather than two more narrow ones, ease of navigation has been claimed for the former. The question to be considered, in the Chicago River, is one of flowing water with only the draw span through which to flow. It occurs to me that perhaps a swing bridge, with two 55-feet openings, as at Madison Street, on the map herewith, would offer more easy navigation than one with 110-feet single opening, as at Van Buren Street. With running water in the river, as will be the case in the future, a mean velocity of 3 feet per second may be fairly expected through the openings, the depth being taken at 16 feet. The cross-section of many boats that will navigate the stream, will be nearly one-half that of the stream through the draw-opening. The effect will be to double the velocity as the boat passes the bridge, or to give a velocity of six feet per second, which increased velocity will oppose quite a resistance to the motion of the boat. In the case of the swing bridge with two clear openings, when the boat has entered one of the openings, nearly all the flow will be forced through the other. The velocity of flow adjacent to the sides of the boat will thereby be diminished, as will also the resistance to motion. I think it is very doubtful whether in this case, where the cross-section of the boat occupies so large a proportion of the cross-section of the stream, there is any advantange in the clear opening over the double.

Again, in the case of boats passing each other. In the case of the double opening, we have in the main Chicago River, or as at the Madison Street bridge, what may be called a double-track passage. Two boats passing each other, each nearly 55 feet wide, in a span of 110 feet, would occupy nearly all the cross-section, and, as one boat passed the other, there would be set up cross-currents which would interfere quite a good deal with the handling of the boats. In the double opening, there is no such thing.

A map, showing the bridge-crossings from Madison Street to Harrison Street, would afford quite a study in this connection. A few more bridges in this region, and there will not be much left of the river. Too long a stretch of single track navigation is being created.

Mr. Liljencrantz.—I think I would agree with Mr. Johnston if the question concerned the way of constructing a bridge in a "straight" channel, but the Chicago River is unfortunately very far from a straight channel, and that is probably one of the main facts that brought about the devices of these three last new kinds of bridges, because in the short bends, in which several bridges are located, the one side (when a swing bridge is used) is frequently impassable by a boat of an average size, and therefore I think that in all such localities the center channel is far preferable. (And as the question of navigation has been taken up, I should like to ask—perhaps more in the interest of navigators than the engineers—inasmuch as Mr. Roberts mentioned, as I understood it, that the "clear channel" at Van Buren Street bridge was 100 feet, I should like to ask if that does not mean the width between the stone abutments, because the clear channel between the protections I have found to be only about 80 feet.)

The President.—Somewhat more than twenty years ago, in conversation with parties as to drawbridges for the Chicago River, I was assured it was a matter of a very short time, two to four years at most, till the traffic in the river would be done with lighters, the larger craft staying in the outside harbor, or going to the Calumet, and all the bridges would be of the fixed type. The prospect of any such change in the navigation interests or the bridges seems more remote than it did twenty years ago. In fact there is not at this time even a suggestion of the probability of any such change; hence it is fair to assume that we are to see much development, with many examples in the way of drawbridges other than the pivot kind so long the standard on the Chicago River.

ASSOCIATION
OF
ENGINEERING SOCIETIES.

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PROCEEDINGS.

Civil Engineers' Club of Cleveland.

CASE LIBRARY BUILDING, CLEVELAND, OHIO, July 9, 1895.—The meeting of the Civil Engineers Club of Cleveland was called to order at 8 P.M., by the President. Present, 22 members and visitors.

The minutes of the last meeting were approved.

Mr. Thompson, Chairman of the Committee on Resolutions upon the death of Mr. A. M. Wellington, reported as follows:

Resolved, That the Civil Engineers' Club of Cleveland learns with sorrow of the death of A. M. Wellington, one of its original members. He was among those who took great interest in its formation and was instrumental in placing it upon its present footing. He was its first representative upon the Board of Managers of the Association of Engineering Societies and was active in the affairs of the Association as well as in those of the Club.

In his death the profession of Civil Engineers sustains a great loss. And we shall miss his substantial contributions to its literature.

We desire to express our deep regret at his untimely decease and to convey to his family our sincere sympathy.

Resolved, That these resolutions be spread upon the minutes of the Club and a copy forwarded to his family.

The resolutions were unanimously adopted. President Mordecai spoke also in eulogy of Mr. Wellington.

The Executive Board reported the resignation of Prof. E. W. Morley, and the transfer from active to corresponding membership of Mr. F. S. Richards.

The Committee on Picnic, through Mr. Jno. L. Culley, reported progress.

Messrs. Palmer and Brown were appointed tellers to canvass ballots for Mr. R. Hoffman.

The Club then listened to the paper of the evening by Mr. Wm. H. Searles, "The Deflections and Stresses of a Flexible Ring Under Load." This description of his original investigations upon the subject was very interesting.

The President gave a short account of the late meeting of the American Society of Civil Engineers at Boston.

The Club voted to hold no meeting at the regular date in August. Mr. Robert Hoffman was announced elected to active membership, and at about 10 o'clock the meeting adjourned.

F. A. COBURN, *Secretary*.

THE LATE A. M. WELLINGTON.

REMARKS BY AUGUSTUS MORDECAI, PRESIDENT OF THE CLUB.

I, perhaps, was as well acquainted with Mr. Wellington as any one present As has been said of him, he was a man of remarkable energy. Blessed with a strong constitution, when any interesting problem really took hold of him he seemed never to tire, even working far into the night and forgetting to stop for his meals.

Born in Massachusetts in 1847, and graduated from the Boston Latin School, he became an articled student in the office of Mr. Henck, of Boston, the author of the well-known field book, and later connected with Mr. Frederick Lew Omstead in the Brooklyn Park Department, then with several railroad enterprises in the South, East and West as assistant engineer on construction. In 1878 he came to Cleveland as an assistant to Mr. Chas. Latimer on what was then the Atlantic and Great Western Railroad; after remaining in that position three years he went to Mexico as chief engineer of the Mexican National, and later became assistant general manager of that line. He returned to the United States in 1884 to become one of the editors of the *Railroad Gazette*, remaining with that influential journal three years, when he associated himself with Mr. Frost, of the *Engineering News*, and was one of its principal editors to the time of his death. During his connection with these journals he also acted as consulting engineer in many important works, making reports on the improvement of Toronto harbor; the abolition of grade crossings at Buffalo; the terminals of the Brooklyn bridge; the railroad system of Jamaica, etc.

He was always a student, and his energetic nature led him early to analyze and study the problems of railroad construction and maintenance. So impressed was he with these problems, and so desirous, as was natural for him, to give to others the benefit of his consideration of them that he early commenced publishing papers on railroad location. In 1874, when but twenty-seven years of age, he published the "Computation of Earthwork from Diagrams." From 1874 to 1878 he commenced his "Economic Theory of the Location of Railways," published as a series of papers in the *Railroad Gazette* and afterwards published in book-form. In 1887, the last edition, a much larger book on railway location, was published by him. He was an indefatigable compiler of facts and figures and a keen analyzer of what they showed. He was a ready and aggressive writer, and had a facility of expression which adds greatly to the value of his books.

My first acquaintance with Mr. Wellington was in 1878, when he was appointed assistant engineer on the Atlantic and Great Western Railroad. The organization at that time was different from what it is now on the New York, Pennsylvania and Ohio Railroads, and there were a number of young men in the office in Cleveland as Mr. Latimer's assistants. We soon came to value him for his real ability, zeal and energy, and for his invariable good humor and cheerfulness. The engineering department was then engaged in working out a number of interesting problems, among others the thorough organization of the department, making it more effective and giving it its true standing in the organization of the road. Among the engineering problems were those of lowering the grades; replacing the wooden bridges with iron ones; improving the permanent way by the adoption of standards for rail sections, frogs, switches, etc.; making complete maps of the line and securing full title to the right of way; work which all railroads, about that time, had to face. Under the admirable leadership of Mr. Latimer each of us had his special work, and Mr. Wellington rendered valuable assistance in many of these lines, more especially in the problems connected with the lowering of the grades, and in editing

the proceedings of the roadmasters' meetings, which Mr. Latimer inaugurated in order to bring more harmonious action and more effective work into his department. He was also busily engaged in carrying on a series of experiments looking to the determination of the axle friction of freight cars, and also, I remember, he reported for some of the technical journals the convention of the Society of Civil Engineers held in Cleveland, besides doing other literary work.

It was during this period that he married and commenced that loving companionship which lasted to the end. His wife was essentially a helpmate to him, accompanying him in all his wanderings, entering into all his plans, and living her life in his, a sacrifice which he certainly returned with a most perfect and true devotion. We do well to tender to her our sincere sympathy in her widowhood.

He was among the first to enter heartily into the idea of the formation of this Club, which owes much to his organizing ability and energy. He was the first, I think, to conceive of the idea of the JOURNAL OF THE ASSOCIATION OF ENGINEERING SOCIETIES. He was our first representative on the Board of Managers of that Association, and, in company with Mr. Benezette Williams and others, he helped largely in assuring its success. He was always interested in the welfare of the Club; and in later years, when I have met him in New York, he has often inquired as to its progress and as to the welfare of its older members.

There are in the profession men more scientific than Mr. Wellington; men more tactful than he; men who will leave monuments larger and greater than his, and yet his place will be found difficult to fill. His best work was, to my mind, the editorship of the *Engineering News.* He brought to that paper a facility of writing, an aggressive and forceful manner full of suggestion and vim, a good, clear understanding as to what a paper of that kind ought to be, and these were invaluable in raising its position and placing it where it now is in the list of technical papers.

In private intercourse he was a warm-hearted, conscientious man, faithful to his work, only wanting that work to be as well done as it could possibly be, not lowering others that he might rise, of even temperament, and although expressing his opinions forcibly, and retaining them with persistence, still carrying with it all a high sense of duty and a sincerity which won him the confidence of those who were fortunate enough to be intimately acquainted with him.

For his genius as a writer, for his ability as an engineer, for his love for his profession, and the purity and simplicity of his character, it is eminently fitting that we should pay a tribute to his memory.

His last illness was brought on by too close application in working out some problems in connection with a suggested change in the steam engine, putting in practical shape some ideas he had long entertained. Even his strong constitution could not stand the protracted want of exercise and of regular meals. We may exclaim with Byron:

> Oh what a noble heart was here undone,
> When science's self destroyed her favorite son.
> 'Twas thine own genius gave the final blow
> And helped to plant the wound that laid thee low.

Association of Engineers of Virginia.

ROANOKE, Va., July 11, 1895.—The regular summer meeting of the Association of Engineers of Virginia convened in Lexington on June 28, 1895, in the chapel of Washington and Lee University. The meeting was called to order by Prof. D. C.

Humphreys, who introduced Hon. William A. Glasgow, the Mayor of Lexington, who delivered an address of welcome, according to the Association the freedom of the town. This address was responded to by the Vice-President of the Association, Mr. M. E. Yeatman, and after the conclusion of his remarks he announced the meeting open for business.

On motion of Mr. H. A. Gillis, the business of the meeting was deferred until Friday morning.

Prof. Humphreys then gave a very interesting talk on the "Improvement of the Mississippi and Missouri Rivers," with which work he was connected for a number of years. He first explained the troubles due to the washing in times of flood and the changes that take place in the river bottoms, and with the help of lantern slides, made from pictures taken on the ground while the work was in progress, he explained the methods used in holding in check the washing and changing of position of channel.

Mr. Newall, of the United States Geological Survey, exhibited and explained to the Association the apparatus used for measurements of the current flow of rivers. This ingenious machine is arranged so that a screw turned by the force of water opens and shuts an electric circuit, which working a sounder registers the speed of the current.

Session then adjourned to meet Saturday, June 29th, at 9.30 A.M.

Saturday, June 29th, meeting called to order by Vice-President, M. E. Yeatman, at 9.30 A.M.

The following report by the committee appointed to recommend a standard gauge for sheet metal and wire was read and unanimously adopted:

To the President and Members:

Your committee appointed to draw up resolutions in regard to the introduction of the Decimal Gauge concludes that it cannot do better than to indorse the resolution adopted by the joint committees of the American Society of Mechanical Engineers and the American Railway Master Mechanics' Association, at their meeting in New York, February 13, 1895, which was as follows:

Resolved, That while the Micrometer Gauge should be used for test purposes in the laboratory, yet for general shop use a solid notched gauge is desirable. The form of this gauge should be an ellipse whose major axis 4 inches, the minor axis 2.5 inches, and the thickness .100 inches. There should be either one hole .750″ diameter in center, or one at each of the foci for lightening and convenience. This gauge must be plainly stamped with the words 'Decimal Gauge' in letters .200″ high, and below this the name of the trade which the group of notches is to cover, these groups to be selected with reference to the needs of the several trades.

All sizes of notches to be marked in thousandths of an inch without a zero prefixing the decimal point, but with inch marks after the figures, thus, .002.″

It is also the intention of this committee that in ordering material the term "Gauge" shall not be used, but merely the thickness in thousandths of an inch.

Your committee also recommends the following rules for the adoption by this Association as standard:

1st. The Micrometer Caliper should be used for laboratory and tool-room work, and in shops when specially desired.

2d. The solid notched gauge should be used for general shop purposes.

3d. The form of this gauge shall be an ellipse whose major axis is 4 inches, the minor axis 2.5 inches, and the thickness .1 inch, with a central hold .75 inch in diameter.

4th. For general railroad purposes the notches may be as follows:

.002″	.022″	.060″	.110″
.004″	.025″	.065″	.125″
.006″	.028″	.070″	.135″
.008″	.032″	.075″	.150″
.010″	.036″	.080″	.165″
.012″	.040″	.085″	.180″
.014″	.045″	.090″	.200″
.016″	.050″	.095″	.220″
.018″	.055″	.100″	.240″
.020″			.250″

5th. All notches to be marked as in the above list.

6th. The gauge must be plainly stamped with the words "Decimal Gauge" in letters .2″ high.

7th. In ordering material the term "Gauge" shall not be used, but the thickness ordered by writing the decimal as in above list. (For sizes over ¼″ the ordinary common fractions may be used.)

G. R. HENDERSON,
CHAS. S. CHURCHILL, } *Committee.*
R. H. SOULE,

The report was unanimously adopted.

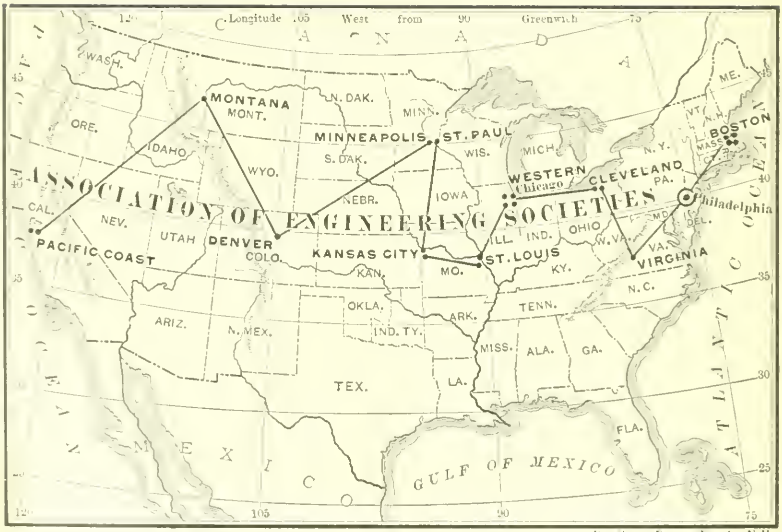
The following names having been duly approved by the membership committee were proposed for membership: Harry Frazier, Richmond, Va.; Wm. F. Wall, Price's Fork, Va.; Samuel M. Barton, Blacksburg, Va., and John T. Worthington, Roanoke, Va. On motion, the Secretary was instructed to cast the ballot of the Association for these members.

Mr. H. A. Gillis, of Roanoke, then read a paper on the "Surface Hardening of Cast Iron," exhibiting quite a number of specimens of cast iron hardened, with chill blocks of various thicknesses, and also of specimens of hardening by a process similar to that used in case hardening wrought iron. This paper brought out much interesting discussion, and on motion was referred to the publication committee.

Col. J. W. Brooks, of the Virginia Military Institute, exhibited the apparatus used by him forty years ago in making "deep sea soundings," and explained the methods and the results obtained. This device, as designed by Col. Brooks, is in principle the same as that now in use, though some improvements have been made in the matter of facilities for handling and by the substitution of steel wire for a hemp cord.

A vote was passed by the Association thanking the Washington and Lee University for the use of their buildings, the Town Council and citizens of Lexington for the hospitable reception given the Association, and the ladies present for their attendance upon the sessions of the Association.

Adjourned. JNO. A. PILCHER, *Secretary.*



Bradley & Poates, Engr's, N.Y.

Association of Engineering Societies.

Vol. XV. AUGUST, 1895. No. 2.

PROCEEDINGS.

Technical Society of the Pacific Coast.

Regular Meeting, August 2, 1895.—Called to order by President Dickie.

Minutes of the last regular meeting of June 7, 1895, approved. Jno. H. Hopps, Lincoln Nissley and Tom W. Ransom were upon ballot declared elected members of the Society.

The Committee on Resolutions relating to the removal of Prof. Geo. Davidson from the head of the Pacific Coast Division of the U. S. Coast and Geodetic Survey reported the following resolutions, which were, on motion, unanimously adopted, and the Secretary was instructed to send copies of the same to our Representatives in Congress and to furnish copies to the newspapers:

Resolved, by the Technical Society of the Pacific Coast: That the Society views with much concern an apparent tendency to curtail the work of purely Scientific Bureaus of the Government, or to transfer it to Departments where political and personal influence will be sure to impair the famous records of such Bureaus.

Resolved, That this Society, seeing additional evidence of this tendency in the removal of Prof. Geo. Davidson from the head of the Pacific Coast Division of the U. S. Coast and Geodetic Survey, expressed regret that he should have been removed without apparent cause, after a life service of the most brilliant character.

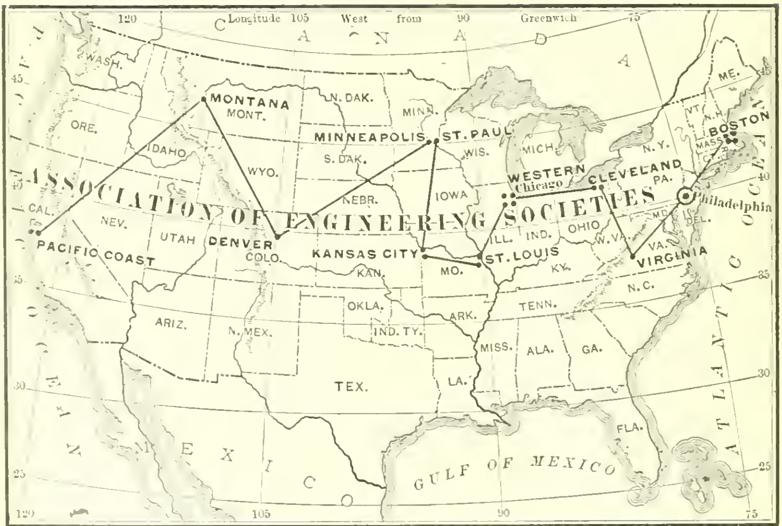
He has by years of efficient and distinguished service shown unusual devotion to scientific work, and his labors have been a credit not only to the Bureau with which he has been connected for nearly half a century, but they entitle him to the lasting gratitude of this Nation and particularly of the residents of this Coast, with whose interest he has so long been identified.

This Society further desires to express the hope that Prof. Davidson, in the vigor of his mature years, may yet find abundant opportunity for satisfactorily utilizing his professional and scientific attainments.

(Signed) John Richards,
Otto von Geldern, } *Committee.*
C. E. Grunsky.

Prof. Chas. D. Marx then read the paper of the evening: "Some Experiments on Water-ram in Pipes," which led to a discussion, in which President Dickie referred to the very interesting experience had on the "Comstock Lode" in connection with the ram in the pipes from deep shafts.

Adjourned. Otto von Geldern, *Secretary.*
Per C. E. Grunsky, *Acting Secretary.*



Bradley & Poates, Engr's, N.Y.

Association of Engineering Societies.

Vol. XV. SEPTEMBER, 1895. No. 3.

PROCEEDINGS.

Civil Engineers' Club of Cleveland.

Case Library Building, Cleveland, Ohio, September 10, 1895.—The meeting of the Club was called to order at about 8 o'clock, by President Mordecai. Present, 31 members and visitors.

The minutes of the last meeting were read and approved.

The reports of the Executive Board for their last four meetings were read and approved. The applications for active membership from Geo. S. Rider and F. A. Smythe were read.

The report of the Picnic Committee, Jos. Leon Gobielle, Chairman, was read, adopted and ordered placed on file.

Mr. Ambrose Swasey reported in regard to the excursion to Lorain. There were fifty-five engineers and visitors in attendance on that occasion.

The paper of the evening, entitled "Educational Architecture," was then read by Mr. Barnum.

Mr. Barnum spoke eloquently of the educative influence of architecture, the greatest of the fine arts; of the present status; the outlook, etc.

He was followed in discussion by Dr. Cady Staley, Architect John Eisenmann, and others.

Some views of the new Boston public library were exhibited at the request of President Mordecai, and that building was offered as an example of some good things that are now being done.

After the meeting, the Club adjourned to one of the vacant stores on the ground floor, and indulged in a light luncheon. F. A. Coburn, *Secretary*.

The Technical Society of the Pacific Coast.

Regular Meeting, September 6, 1895.—Called to order at 8.30 p.m., by President Dickie. The minutes of the last regular meeting were read and approved.

The following applications were read and referred to the Executive Committee, for members:

W. F. Englebright, Civil Engineer, of Nevada City, proposed by Hubert Vischer, Geo. F. Schild and Otto von Geldern.

Dana Harmon, Mining Engineer, of Nevada City, proposed by John W. Gray, Hubert Vischer and L. J. LeConte.

W. W. Waggoner, Mining Engineer, of Nevada City, proposed by C. E. Grunsky, Hubert Vischer and Adolph Lietz.

Mr. Edward S. Cobb then read the paper of the evening, explaining in detail the design of a large wrought-iron wheel. A discussion of the subject ensued.

The President then referred to the present condition of the Technical Society, and suggested the advisability of holding meetings of a social character, in order to bring together all the elements of the Society. Such meetings should be held at regular intervals, and might take the form of a dinner. After discussing the subject, it was moved that the Board of Directors make the necessary arrangements for a social gathering—or dinner—at the time of the next regular meeting in October, and that the Secretary be instructed to send the necessary circulars of information to the members, after the action of the Directors.

Adjourned. OTTO VON GELDERN, *Secretary.*

Engineers' Club of St. Louis.

421ST MEETING, SEPTEMBER 18, 1895.—President Russell called the Club to order at 8.30 P.M., at 1600 Lucas Place, fifteen members and two visitors present.

Mr. A. L. Johnson opened the discussion on "The Inspection of Structural Steel," the subject being of special interest just now on account of the widespread attention which has recently been given it in the columns of the *Engineering News.* Mr. Johnson stated the ordinarily accepted definitions of the terms "elastic limit," "yield point," and "break-down point." He showed the extreme difficulty of determining these characteristics, particularly with very high grade steel, such as is used in drawn wire. He doubted seriously whether any existing method gave us an exact determination of these points. He doubted furthermore, whether it was necessary to know them, as the ultimate strength and elongation told us all that was really essential for us to know about any material. In his opinion, advanced practice would warrant the omission of the elastic limit in all specifications.

Mr. Robt. Moore agreed fully with Mr. Johnson. The elastic limit being uncertain and difficult of determination, he had for some years omitted it entirely from his specifications.

Prof. J. B. Johnson called attention to the fact that for all commercial purposes the three points, elastic limit, yield point, or break-down point, were one and the same, and need only be considered separately in an abstract scientific study of the subject. He showed charts from tests recently made by Prof. Grey at Terre Haute, made on what is perhaps the best apparatus in existence for the purpose. These showed a practically straight line from the origin to the yield point.

Mr. Bryan thought that we should not lose sight of the elastic limit, for the reason that it and not the ultimate strength indicated what could be done with a material. It was important to know when the structure would begin to distort seriously, rather than when it would fail altogether. He thought it would be better to use reduced factors of safety, based upon the yield point rather than the ultimate strength. In reply, Mr. Moore stated that the ultimate strength and elongation were properties which could be readily and accurately determined, and that in all standard materials the elastic limit bore a certain relation to the ultimate strength, which relation did not vary materially.

President Russell called attention to the difficulty which the designing engineer met with in using the accepted formulæ when so much uncertainty existed as to the elastic limit.

WILLIAM H. BRYAN, *Secretary.*

Boston Society of Civil Engineers.

SEPTEMBER 18, 1895.—A regular meeting was held at the Society rooms, 36 Bromfield Street, Boston, at 7.50 o'clock, P.M., President Albert F. Noyes in the chair. Sixty-seven members present.

The record of the last meeting was read and approved.

Mr. John F. Lyman was elected a member of the Society.

The report of the Committee on Weights and Measures submitted at the last meeting and referred to this meeting for action, was recommitted to the Committee for a full report.

The Secretary presented an engrossed copy of the resolution of thanks to this Society passed by the American Society of Civil Engineers at its annual convention in June last.

A communication was also read from Mr. O. Chanute, transmitting a photographic reproduction of a vote of thanks passed by the German Society of Engineers to the associated societies which maintained the engineering headquarters at Chicago during the World's Fair.

Mr. Howe gave notice in writing of a proposed amendment to By-law 1, changing the night of meeting from Wednesday to Friday.

The President announced the deaths of Willis H. Hall which occurred August 26, 1895, and Marshall M. Tidd, which occurred August 20, 1895, and by vote of the Society he was requested to appoint committees to prepare memoirs.

Mr. Percy N. Kenway read the paper of the evening entitled "A Study of the Heating and Ventilating Plants in the Suffolk County Court House and in the Massachusetts State House." The reading of the paper was followed by a discussion in which Prof. S. H. Woodbridge, who designed the State House plant, Mr. Frederic Tudor and others took part.

Adjourned. S. E. TINKHAM, *Secretary.*

Adelbert L. Sprague.—A Memoir.

BY FRANK A. FOSTER AND FRANK O. WHITNEY, COMMITTEE OF THE BOSTON SOCIETY OF CIVIL ENGINEERS.

[Read June 12, 1895.]

Adelbert Leroy Sprague, son of William F. and Abbie J. Sprague, was born in Foxboro, Mass., October 23, 1872.

His parents removed to Boston in 1883, from which time he attended the Bigelow Grammar and English High Schools until his graduation from the latter in 1888.

He entered the City Surveyor's office, Boston, immediately after leaving school at the age of fifteen, being the youngest person ever employed in that department.

For five years he served the city with characteristic fidelity, rising from the position of rodman to that of an assistant surveyor.

In March, 1893, he gave up his position in the city service to take a more responsible one with the Brookline Gas Light Co., where he was engaged in work connected with the extension of their business into the city of Boston.

In June, 1894, he left the company's service and entered the office of Mr. Frank A. Foster; his work in that office was on the preliminary survey of the Middlesex Fells and Lynn Wood s Park Way, and later on the Blue Hills Park Way.

He was joined in marriage to Miss Mabel Lord, only three months before his death, which occurred April 12, 1895.

Although cut off at an early age he had gained for himself a reputation for carefulness and competency attained by few of maturer years.

His modest bearing, genial disposition and devotion to his profession endeared him to his friends and impressed all who knew him.

Association of Engineering Societies.

Vol. XV. | October, 1895. | No. 4.

PROCEEDINGS.

Western Society of Engineers.

The Annual Pleasure Outing of the Society was an excursion to Milwaukee by the steamer "Indiana," Monday evening, August 5, 1895, arriving Tuesday morning. The attendance was not large, but the trip was a very enjoyable one. During the forenoon the party visited the new Sixteenth Street viaduct and Bascule Bridge, the shops of the Edward P. Allis Co., and the Chicago & Northwestern Railway drawbridge, operated by a gas engine. In the afternoon, carriages were taken for a drive about the city under escort of Mr. M. G. Schinke, Assistant City Engineer, visiting the new City Pumping Works, and Pabst's Brewery. Return to Chicago was by steamer "Virginia," on Tuesday evening.

A Special Meeting (332d) of the Society was held in the Society's rooms, Wednesday evening, August 7, 1895, for consideration of the action of the Board of Managers of the Association of Engineering Societies on the recommendations made to them by the Western Society of Engineers with reference to the conduct of the Journal, and also for the determination of the course the Western Society is to pursue with reference to the Journal. President Horton in the chair, and sixteen members present.

The objects for which the meeting was called were fully discussed by various members.

On motion of Mr. Robt. W. Hunt, it was voted "That the Board of Managers of the Associated Societies be requested to render the societies in the Association a financial statement for the first quarter of the present year, and for each quarter thereafter, showing the cost of the Journal, the number of members in each Society on the Journal mailing list, the amount of money paid by each Society, and the amount any Society is delinquent."

The following resolution was presented by Mr. J. J. Reynolds, and was duly seconded:

Resolved, That the Western Society of Engineers withdraw from the Association of Engineering Societies, and that the Secretary of this Society notify the Association of such action.

A letter ballot on the above resolution was demanded by five members: Messrs. J. J. Reynolds, Alex. E. Kastl, Ebin J. Ward, Frank P. Kellogg and B. E. Grant —under the provisions of Section 2, Article V of the Constitution, and the Presi-

dent announced that therefore a letter ballot would be taken on the resolution. Adjourned.

CHARLES J. RONEY, *Secretary.*

The invitation of the Chicago Ship Building Company, through its manager, Mr. W. I. Babcock, member of the Society, for the Western Society of Engineers to be present at the launching of the steel steamer "Zenith City," on Wednesday afternoon, August 14, 1895, was accepted by about 75 members and their friends.

For this enjoyable occasion and courtesies tendered, thanks are also due to the Shailer & Schniglau Co., the Fitz Simons-Connel Co., Messrs. O. B. Green and J. J. Reynolds, and to our efficient Excursion and Entertainment Committee, through whose joint efforts this junket was made without drawing on the Society's funds.

It is regretted that the time of notification to the Committee precluded sending invitations by mail to non-resident members.

THE 333D MEETING of the Society was held in the Society's rooms, Wednesday evening, September 4, 1895. President Horton in the chair, and thirty-five members present.

The minutes of the meeting of June 5th (331st), and of the Special Meeting of August 7th (332d), were read and approved.

The Secretary reported for the Board of Directors:

Applications for membership have been received and filed as follows:

As Members, James C. Long, U. S. Asst. Engineer, Tiskilwa, Ill., and John Cornelius Bley, Mechanical Engineer, Chicago.

At the meeting of the Board of Directors held July 2, 1895, the Treasurer reported a balance on hand, July 1, 1895, of $2,072.47.

Bills to the amount of $1,062.44 were approved and ordered paid. The above amount includes bills from the Association of Engineering Societies for the Final Assessment for 1894, and for the first and second quarterly assessments for 1895, amounting to $840.30.

Mr. Thos. T. Johnston was elected as Representative of the Society on the Board of Managers of the Association of Engineering Societies *vice* Mr. Thos. Appleton, resigned.

At the meeting held August 6, 1895, the Treasurer reported a balance on hand August 1, 1895, of $1,403.35.

Bills to the amount of $134.28 were approved and ordered paid.

The President announced the resignation of Mr. L. E. Cooley as a member, on the part of the Western Society of Engineers, in the Chicago Municipal Improvement League, and the appointment of Mr. Thos. T. Johnston to serve the remainder of the unexpired term.

The matter of letter ballot on the question of withdrawal from the Association of Engineering Societies was then discussed. The unanimous sense of the meeting was that the votes should be returnable on September 24th, and the result announced at an adjourned meeting at Armour Institute, on the evening of that day.

The Secretary announced the death of Mr. Wm. A. Hammett, a member of the Society, and requested information from members regarding Mr. Hammett's life and professional career.

The Secretary also read a letter from Mr. O. Chanute, accompanied by a translation of a letter from the Society of German Engineers, and a photograph

of an artistic memorial, expressing the thanks of the Society of German Engineers for the reception given its members by the Associated Engineering Societies at their headquarters in Chicago, during the summer of 1893, and the matter was, by vote, referred to the Board of Directors for suitable action.

The Secretary then read an invitation to the Society to appoint delegates to attend the First Annual Convention of the International Deep Waterways Association, to be held at Cleveland, Ohio, September 24, 25, 26, 1895, and the matter was referred to the Board of Directors with power to act. On motion, the meeting adjourned to meet at the Armour Institute of Technology, on Tuesday evening, September 24, 1895, at 8 P.M.

The adjourned (333d) meeting of the Society was held in Science Hall, Armour Institute of Technology, Tuesday evening, September 24, 1895. President Horton in the chair, and fifty-five members and guests present. The Secretary read the following report:

September 24, 1895.

The Western Society of Engineers:

We, the undersigned Judges of Election, appointed by the Board of Directors, having duly canvassed the vote cast on a special election, closing at 3 P.M., September 24, 1895, on the following resolution:

"*Resolved*, That the Western Society of Engineers withdraw from the Association of Engineering Societies, and that the Secretary of this Society notify the Association of such action," report as follows:

Total number of votes received	269
Rejected for informality	3
Total votes counted	266

of which 87 votes were No, and 179 votes were Yes.

Respectfully submitted,

WM. B. EWING,
JOHN W. ALVORD,
Judges of Election.

The President announced—The vote is in the affirmative, the ayes being in the majority, the resolution is carried, and the Secretary will give proper notification.

Mr. Ambrose V. Powell then read his paper, "Some Notes on the Dry Docks of the Great Lakes," illustrated by many fine lantern views, which were fully described as presented, and, after further interesting remarks by Mr. Powell, the meeting adjourned.

CHARLES J. RONEY, *Secretary.*

Engineers' Club of St. Louis.

422D MEETING, OCTOBER 2, 1895.—The President announced the death of Alex E. Abend, and stated that Mr. Edward Flad had consented to prepare a memorial for presentation at an early meeting.

On behalf of the committee, Mr. Robert Moore then presented to the Club the oil portrait of Colonel Henry Flad. His remarks were as follows:

Mr. President and Gentlemen:

Early in the present year several members of the Engineers' Club of St. Louis formed themselves into a committee to secure an oil portrait of Col. Henry Flad

for presentation to the Club. In the belief that many other members would esteem it a privilege to join in this undertaking, a circular letter was sent to every member, offering him the opportunity to contribute thereto. The response to this circular justified our expectations, and the requisite amount of money was easily secured. The committee thereupon engaged as artist, Mr. Chas. F. von Saltsza, of the St. Louis School of Fine Arts, who had executed some most admirable works of this character, and, what was no less important, secured also the co-operation of Col. Flad to assist the artist with sittings. The result is a portrait which a number of the intimate friends of the Colonel pronounce an excellent likeness, and which we think will commend itself as such to the Club at large.

To those who have had the privilege of a personal acquaintance with Colonel Flad, and the opportunity of knowing at first-hand his high personal and professional qualities, nothing need be said in justification of any steps to perpetuate his memory. To those who have not been thus fortunate, it will be enough barely to recall his honorable record as captain and then as colonel of a Missouri regiment of engineers during the late war; his service after the war as assistant to Mr. Kirkwood in designing the St. Louis water works, and then as a member of the Board of Water Commissioners, under whose direction these plans were carried out; his brilliant engineering work as a colleague with Captain Eads in the construction of the St. Louis bridge; his presidency of the American Society of Civil Engineers, and his twelve years' term as president of the Engineers' Club of St. Louis, of which he was a charter member; his fifteen years of service as president of the Board of Public Improvements of St. Louis, during which time the public works of the city were conducted with a fidelity and skill unsurpassed in any city of the world; and last, his present work as one of the most active members of the Mississippi River Commission. As soldier, as citizen, and as engineer, his career has always been marked by distinguished ability, unswerving integrity, and absolute devotion to the public good. No citizen is more worthy of perpetual remembrance in St. Louis than is Col. Henry Flad.

It is with no ordinary pleasure, therefore, that, on behalf of the committee and all those who have shared in this enterprise, I now present his portrait to the Engineers' Club of St. Louis, trusting that it may be long preserved as a reminder of his great public services, and as a continual source of pride and inspiration to the members of the Club.

Mr. Richard McCulloch then read a paper on "The Continuous Rail in Street Railway Service." He described briefly the work done in St. Louis and elsewhere, and the processes employed. The paper was illustrated by drawings, photographs, rail sections, and samples of joints. Two systems had been employed in St. Louis, electric welding and cast welding. The latter, requiring a less expensive plant, being simpler and easier to operate, and the work appearing to stand service better, had been given the preference. In spite of the extreme temperatures but a very small percentage of the joints had broken, and these were clearly due to defective welds. The cost was not greatly in excess of the old fish-plate method. It was thought that the rail being surrounded by earth or paving on all sides except the top, it was protected from the extreme variations of temperature and being held rigidly in position, these two features tended to counteract the expansion and contraction which would ordinarily be expected.

WILLIAM H. BRYAN, *Secretary.*

423D MEETING, OCTOBER 16, 1895.—President Russell called the Club to order at 1600 Lucas Place at 8.30 P.M. Twenty-two members and six visitors present.

Mr. Edward Flad read the following memorial:

"Alexander E. Abend was born at Belleville, Ill., in 1859. He received his education at Washington University, in this city, graduating from that institution in 1881 with the degree of C.E.

"For the first few years after leaving the university he devoted himself almost

entirely to railroad work, being employed as assistant engineer and division engineer on the Northern Pacific Railroad and the Oregon and California Railroad. Returning to Belleville in 1885, he was appointed to the position of constructing engineer and superintendent of the City Water Works of Belleville.

"Later he opened an office as Surveyor in East St. Louis, and in 1893 was appointed to the position of city engineer for that city.

"An era of improvement had begun in East St. Louis; large amounts of money were expended in grading and paving streets, constructing sewers and other public works. As city engineer such improvements were conducted under his supervision. The ability which he displayed in designing and carrying out this work is perhaps best attested by the fact that upon the election of the present mayor, some months ago, Alex. Abend was reappointed to the position of city engineer, although his sympathies were known to have been with the defeated candidate.

"Those of us who were his classmates at the university—and this Club numbers six such among its members—will remember Alex. Abend as a conscientious student, fair-minded, honest, possessed of good sound judgment, and a companionable disposition. He had those qualities which would lead one to predict a useful life, endeared with ties of love and friendship. And such was his life until an over-wrought nature succumbed to mental worry, and unable to longer bear up against the cares which beset him, he, with his own hands, put an end to the struggle on the afternoon of September 18, 1895.

"To his widow and family our deepest sympathy is extended."

Ordered that this memorial be spread upon the records of the Club.

President Russell then gave the Club the results of some tests on bronze for tension and compression, made by the Washington University testing laboratory for the water works extension. Tables of the results, with charts and diagrams, were shown. Messrs. Flad, Baier, A. L. and J. B. Johnson, Holman and Moore took part in the discussion. It was shown that the compressive strength of metals which flow could not be determined.

Mr. William H. Bryan then read a paper on "Pamphlet Filing," explaining the difficulties he had met with in filing and indexing the many kinds of pamphlets which an engineer receives, and giving his solution of the problem, showing how all the data on any one of more than a hundred different subjects could be immediately located.

Discussion followed by Messrs. Holman and Flad.

Mr. M. L. Holman then explained the break which occurred on Saturday, 12th inst., in the dividing wall between two reservoirs at the Chain of Rocks. The water had broken down through the concrete bottom of a full reservoir, and up into the adjoining empty reservoir. The concrete foundation had been entirely washed away, but the wall itself was intact, leaving a span of nearly 60, and a depth of 15 feet. It was proposed to repair it by concrete foundation under the wall, and puddling work under the concrete bottom.

Attention was called to the necessity of making provision for expansion and contraction of long masonry walls when built as monoliths. It was found in practice that walls which were perfectly tight in summer developed cracks of considerable area in winter. These were stopped by packing them with oakum dipped in cement, which required renewal every winter.

Messrs. Flad, Crosby, Johnson, Russell and Bryan participated in the discussion.

Civil Engineers' Society of St. Paul.

October 7, 1895.—A regular meeting of the Civil Engineers' Society was held at the Society room at 8.15 p.m. Vice-President Hilgard presided. Fourteen members and eleven visitors were present.

Minutes of previous meeting were read. An invitation from M. Jules Lermina, Secretary, to join the International Literary and Artistic Association, was referred to Mr. Estabrook and Mr. Münster.

The Committee Report of the Board of Regents of the University of Minnesota on the State Survey, was placed on file.

A communication from Mr. Thomas Egleston, touching a standard metric wire gauge, was referred to Messrs. Crosby, Lyon, Hogeland, Toltz and Merryman.

A memorial circular from Secretary F. R. Hutton, of the Am. Soc. M. E., on the death of President Davis, was referred to Mr. Lyon and Mr. Crosby.

A letter of instruction as to the preparation of matter for the Journal of the Association was placed on file.

A letter from Chairman J. B. Johnson, asking proposals for Journal exchanges, was referred to Mr. Münster and Mr. Woodman.

The Secretary was instructed to reply to the invitation of the Western Society of Engineers to attend the excursion of October 12th to the Drainage Canal.

Mr. Hew Miller was elected to membership.

Mr. A. O. Powell read an interesting and fully illustrated paper on Sluice Gates and Movable Dams of the Bear-Trap Type. The bear-trap gate is an American device of eighty years ago, but lately modified and improved. The French condemned it after an experimental trial of a gate wrongly proportioned, apparently considering it unworthy of scientific study. Mr. Powell has investigated the bear-trap gate mathematically, and will prepare his paper for publication in the Journal of the Association.

Mr. R. A. Lang, of Eau Claire, Wis., a builder and inventor of bear-trap gates of eighteen years' experience, briefly touched on a few points of interest, after which the meeting adjourned to Neuman's, at 11 o'clock, to spend a pleasant social hour.

C. L. Annan, *Secretary.*

Civil Engineers' Club of Cleveland.

Meeting of the Civil Engineers' Club of Cleveland, October 8, 1895.—Present, thirty-two members and friends. Minutes read and approved.

Messrs. C. M. Barber and C. F. Lewis were appointed tellers to canvass ballots for the election of Mr. George S. Rider and Frank A. Smythe.

Communications from the Board of Managers of the Associated Societies were read. They referred to the withdrawal of the Western Society from the Association, and to the new rules proposed for governing the management of the Journal, agreeable to the late voting of the members of the Societies.

The report of the Executive Committee was read, telling of the proposition of the Library Board to turn over our library to the care of The Case Library. After some discussion, the Club voted to do so. The Secretary was directed to send cards to the members, telling of the invitation from the Western Society to visit the Drainage Canal, and to extend our thanks to the Society for their kind invitation.

Messrs. George S. Rider and Frank A. Smythe were declared elected to active membership.

Prof. J. W. Langley, of the Case School of Applied Science, then gave a talk upon the Electrical Purification of Sewage. He told of the practical success of the system, where now in use, and gave figures from his own experiments, showing its economy.

He was followed by Prof. Benjamin, of Case School, with a brief and interesting paper upon "The Development of Mechanical Science in the World's History."

The Club then adjourned to the Hamilton Restaurant and participated in a light lunch.

F. A. Coburn, *Secretary.*

Boston Society of Civil Engineers.

October 16, 1895.—A regular meeting was held at the Society rooms, 36 Bromfield Street, Boston, at 7.50 p.m. President Noyes in the chair. Eighty-three members and visitors present.

The record of the last meeting was read and approved.

Messrs. Frank S. Badger, Harry C. Bradley, John R. Burke, Alfred D. Flynn and William E. McKay were elected members of the Society.

The Committee on Weights and Measures submitted a report recommending the adoption of the following resolution:

Resolved, That the Boston Society of Civil Engineers earnestly deprecate the use of any of the wire and sheet metal, or other trade gauges now in vogue, and strongly urge the use of millimeters and decimal fractions thereof for all such measurements.

The report was received and action on the resolution deferred until the next meeting.

The amendment to By-law 1, proposed at the last meeting, changing the night of the regular meetings from Wednesday to Friday, was not adopted.

The President reported that an agreement had been reached with the Trustees of the new Tremont Temple for the leasing of rooms for the Society's use, and that arrangements had been made with the New England Water Works Association and the Hersey Manufacturing Company for the joint use of these rooms. On motion, the President and Treasurer were authorized to execute a lease for these rooms, in accordance with the terms reported by the President.

Mr. J. A. Tilden, for the committee appointed to prepare a memoir of John H. Webster, submitted its report, which was read and accepted.

The thanks of the Society were voted to Lt.-Col. S. M. Mansfield, Corps of Engineers, U. S. A., for courtesies shown its members on the occasion of the visit to the Government Battery at Winthrop.

Mr. Allen Hazen then read the paper of the evening, entitled "The Present European Practice in Regard to Sewage Disposal." The paper was discussed by Messrs. Fitzgerald, Porter and others. Adjourned.

S. E. Tinkham, *Secretary.*

John H. Webster.—A Memoir.

By James A. Tilden and John R. Freeman, Committee of the Boston Society of Civil Engineers.

[Read October 16, 1895.]

It is with deep regret that we have to record the death of Mr. John H. Webster, a member of the Boston Society of Civil Engineers and also of the American Society of Mechanical Engineers. He passed away April 2, 1895, in the House of the American Society in New York, where he made his home when in that city. He was very nearly forty-five years of age, in the prime of life and at the period of his greatest value to the profession. The end found him at what he felt to be his post of duty, regardless of his physical condition; he was, as afterwards appeared, dangerously ill when he left his home in Boston for New York, two days before. His engineering work was almost his only recreation, and upon this he was habitually engaged from early in the morning until far into the night, so that when pneumonia overtook him it found him completely worn out and an easy victim.

As an engineer he was unusually able and energetic; as a gentleman he was entirely honorable and unassuming; and as a friend he was absolutely steadfast and true. He was most essentially a self-made man, as a reading of his application papers for membership to the engineering societies will show. His rare mechanical and inventive talent was first discovered and brought out when he was but nineteen years of age by Mr. L. D. Hawkins, and for six years thereafter he was engaged by that gentleman and others in designing general machinery. At the age of twenty-five he was engaged as head draughtsman in the reconstruction of the Standard Sugar Refinery of this city, at twenty-seven he became the Assistant Superintendent, and at thirty the Superintendent of the Refinery, in which position he remained for about ten years, making many valuable improvements for the refinery, and a reputation for himself.

At the organization of the American Sugar Refining Company in 1890, into which the Standard, among other refineries, was merged, Mr. Webster was made one of the Consulting Engineers, with headquarters in New York, dividing his time weekly between that city and Boston. This was the position he held at his death.

His whole life was an honor and a credit to the engineering profession, and what he gave to the world in design and invention are lasting monuments to his memory.

Montana Society of Civil Engineers.

Helena, Mont.—At the last meeting of the Montana Society of Civil Engineers, held Saturday evening, October 12th, in the rooms of the Society in the annex of the Granite Block, Mr. Keerl, who was appointed to confer with the librarian of the public library with reference to the best books on the subject of engineering that could be secured for the library, made a report. He said that he had given the subject a good deal of attention, and had recommended certain books which he hoped would be secured at an early date. He realized, he said, that the selection of a limited number of books on so comprehensive a subject was a matter for serious consideration, but he hoped that the selection he had made would meet with the approval of the Society.

It was voted that the Society donate to the library six volumes of the JOURNAL OF THE ASSOCIATION OF ENGINEERING SOCIETIES, which would put the library in possession of all the copies of the JOURNAL since 1888.

A letter from Prof. J. B. Johnson, Chairman of the Board of Managers of the Association of Engineering Societies, was read, which contained the information that the Western Society of Engineers, of Chicago, had voted to withdraw from the Association. Prof. Johnson also called attention to the fact that new officers of the Association would soon be elected, and that, owing to other duties, he would be compelled to decline a renomination. This was much regretted by all, as they all realized that Prof. Johnson had been untiring in his efforts to promote the good of the Association.

A committee consisting of Elliott H. Wilson, of Butte; Edward R. McNeill, of Boulder, and Charles G. Griffith, of Helena, was appointed to nominate officers for the ensuing year.

The members present were: James S. Keerl, W. A. Haven, John Herron, A. E. Cumming, H. V. Wheeler, James H. Henley and F. J. Smith.

Bradley & Poates, Engr's, N.Y.

Association of Engineering Societies.

Vol. XV. NOVEMBER, 1895. No. 5.

PROCEEDINGS.

Western Society of Engineers.

The 334th Meeting of the Society was held in the Society's rooms, Wednesday evening, October 2, 1895. President Horton in the chair and forty-one members and guests present.

The minutes of the meetings of September 4th and 24th were read and approved.

The Secretary reported for the Board of Directors as follows:

At the meeting of the Board of Directors held September 7, 1895, the resignation of Mr. Benezette Williams as a representative of the Western Society of Engineers on the Board of Managers of the Association of Engineering Societies was read and accepted, and Mr. Charles J. Roney has been since appointed to serve the remainder of the unexpired term.

The following persons were elected to membership:

As Members—Messrs. John C. Bley and James C. Long.

The Treasurer reported a balance on hand September 1, 1895, of $1,599.43.

Bills to the amount of $138.83 were approved and ordered paid.

At the meeting of the Board of Directors held October 1, 1895, the following applications for membership were received and placed on file:

As Member—Lyman Smith, Chicago.

As Associate—Rudolph Link, Chicago.

Bills to the amount of $187.06 were approved and ordered paid.

Mr. Gerber, chairman of the Excursion and Entertainment Committee, announced a proposed Drainage Canal Excursion for October 12th, by special train to Lemont, thence returning, stopping at various points; luncheon to be served at some point on the trip; further announcements to be made.

On motion, after explanation of the need of such action, it was *Resolved*, That a committee of three be appointed by the chair, to report at the next regular meeting of the Society (November 6, 1895), a plan for the publication of the papers and proceedings of the Society and a revision of the Constitution and By-Laws.

The Secretary announced the death, a few hours previously, of General O. M. Poe, Col. of Engineers, U. S. A., one of the oldest members of the Society, and a committee was appointed to draft appropriate resolutions thereupon,

The Secretary reported the list of delegates from the Western Society of Engineers to the First Annual Convention of the International Deep Waterways Association, at Cleveland, Ohio, September 24, 25, 26, 1895, as follows: Members—Gen. O. M. Poe, Lyman E. Cooley, Isham Randolph, Thos. T. Johnston, Alex. E.

Kastl and Ebin J. Ward. Associates—Frank Wenter, William Boldenweck, Bernard A. Eckhart, and Capt. James S. Dunham. All these delegates attended the Convention, except Gen. Poe, who was unable to do so.

On motion the chairman was instructed to appoint delegates from the Western Society to the Western Waterways Convention at Vicksburg, Mississippi, October 22 and 23, 1895. Messrs. Lyman E. Cooley and Thomas T. Johnston were subsequently appointed delegates.

A memoir of Warren Collier Smith was read, ordered spread upon the records of the Society, and a copy sent to the family of the deceased.

A discussion on "The Proper Chemical Composition of Steel for Heavy Rail-sections" was then opened by Mr. Robert W. Hunt, and a very interesting presentation of the subject was made. The meeting then adjourned.

On Saturday, October 12th, a very delightful excursion was made to various points of interest on the Chicago Sanitary Drainage Canal. By the courtesy of the Chicago & Alton Railroad Company a special train was secured, and a luncheon was served on the train. About 225 members and guests, including many ladies, participated.

At the meeting of the Board of Directors, held October 15th, the following applications for membership were received and placed on file.

As Members: Waldo H. Marshall, Mechanical Engineer, and Editor of the *Railway Master Mechanic*, Chicago, and Charles Woodbury Melcher, Mechanical Engineer, and Chicago Manager The Ingersoll-Sargeant Drill Co., Chicago.

Charles J. Roney, *Secretary*.

Warren Collier Smith.—A Memoir.

By Isham Randolph, Frederick S. Brown and James J. Reynolds,
Committee of the Western Society of Engineers.

[Read October 2, 1895.]

The subject of this memoir, Warren Collier Smith, was born in Clark County, Va., on June 28, 1866. His parents were Warren Christian Smith and Betty B. Smith (*née* Randolph.) The home influences which surrounded the boy were such as tend to the up-building of a sturdy, honest and honorable character, and they bore fruit in him of the truest manhood.

The circumstances of his life debarred him from a broad and liberal education, but such educational advantages as were vouchsafed him he improved faithfully, grounding himself well in the English branches and in the basic principles of mathematics.

In 1886, he secured employment in the Engineer Corps of the Chicago, Madison and Northern Railroad in a very subordinate position. His steady, industrious habits and close observation, coupled with his aptness to learn, attracted the attention of his superiors, who extended to him the opportunities which he needed of becoming familiar with the use of instruments and acquiring practice in the computations of field and office.

Upon the completion of that work, he secured employment in West Virginia, on railroad location and construction, in a responsible capacity. Later, he was

employed upon the Chicago and Eastern Illinois Railroad, in charge of the second track graduation between Dalton and Momence. After this, he was engaged upon the surveys and construction of the Chicago and Calumet Terminal Railroad. Following this, he entered the employ of Mr. W. F. Sargent, Engineer and Surveyor of this city, and, for the last three years of his life, he was associated with his uncle, Isham Randolph, in charge of the land survey branch of his business.

He was quiet and unassuming, but forceful and determined, a man who impressed all with whom he come in contact, either in the business of life or in its friendly relations, with his unfaltering integrity, his high sense of honor and his kindliness of heart. To us who knew him in the daily intercourse of life, he was genial and affectionate, a friend to be loved and trusted in life, and sincerely mourned in death.

He died on the 29th of March, 1895, at the home of his mother in Jefferson County, West Virginia, leaving a short record of years, full of honest, earnest work and loyal devotion to duty and friendship.

Engineers' Club of Minneapolis.

October 14, 1895—A special meeting, to which other engineers of Minneapolis had been invited by the Engineers' Club of Minneapolis, was held at the office of the City Engineer, City Hall, to take action upon the death of William A. Pike, C. E., which occurred on Sunday, October 12, 1895.

The meeting was called to order at 8 P.M. by the President, F. W. Cappelen, who in fitting words announced the great loss which both the Club and the profession had sustained, after nearly all present had paid fitting tribute to our deceased member. I. E. Howe moved that a committee of three be appointed to draft suitable resolutions and present them to this meeting for adoption. This was amended, increasing the committee to five, and adding "and that this committee make arrangements for flowers, and attend the funeral as representatives of this meeting," and so carried.

The Chair appointed, as such committee, I. E. Howe, M. D. Rhame, E. T. Abbott, Wm. De La Barre, and Elbert Nexsen.

The following resolutions were drawn up, reported and unanimously adopted:

Whereas, Death has removed from our midst an esteemed associate and friend in the person of William A. Pike, and we wish to express our appreciation of him as a man and civil engineer.

Resolved, That we do hereby express our sincere sorrow at the death of William A. Pike, feeling that in him the engineering profession had a faithful and able representative, whose character and abilities gave promise of a most useful and honorable future. In him we recognized such strongly marked traits of character, such high aims, such devotion to his profession, such honesty of purpose as to win our admiration and command our highest respect.

We extend our sympathies to the wife and family of our departed colleague, realizing that a great personal loss has been sustained by those intimately associated with him in his lifetime.

Resolved, That an engrossed copy of these resolutions be transmitted to his bereaved family.

Elbert Nexsen, F. W. Cappelen,
Secretary. *President.*

On motion, adjourned. Elbert Nexsen, *Secretary.*

NOVEMBER 22, 1895.—A meeting of the Engineers' Club of Minneapolis was held at the office of the City Engineer, City Hall, at 8 P.M., the President in the chair, to consider the advisability of continuing the Club next year, or winding up its affairs with this year.

A statement was made showing the indebtedness of the Club, which was entirely due to the JOURNAL OF THE ASSOCIATION OF ENGINEERING SOCIETIES. A canvas of the amounts due from members showed that this had arisen by neglect of members to keep their assessments paid up—that there was enough due which was considered good to meet our liabilities. The sentiment expressed by all present was that this must be collected and the debt paid early in December, and that the Club had better die than drag along as it had for the last few months.

W. R. Hoag moved a committee of three be appointed to see all members in arrears, and point out to them that this debt must be paid at once, and unless they paid up their arrearages those who had must do it for them. Carried. Chair appointed W. R. Hoag, F. W. Cappelen and Elbert Nexsen, committee.

The Secretary read a letter from Mrs. Maria R. Pike, expressing her thanks and those of her family for the action of the Club in reference to the death of her husband, Mr. William A. Pike.

Adjourned, subject to the call of the President.

ELBERT NEXSEN, *Secretary.*

Technical Society of the Pacific Coast.

NOVEMBER 1, 1895.—Regular meeting. Called to order at 8.30 P.M., by President Dickie.

The minutes of the last regular meeting were read and approved.

The following gentlemen were elected to membership by regular ballot :

Members.—W. F. Englebright, Dana Harmon and W. W. Waggoner, all of Nevada City, California.

The proposition for membership of Dr. Willis E. Everette, Mining Engineer of Tacoma, Washington (proposed by George F. Schild, H. C. Behr and Otto von Geldern), was referred to the Executive Committee.

Professor Frank Soule then read the paper of the evening, entitled :

"Pacific Coast Timber, Its Tests and Treatment," which was fully discussed by members present.

Adjourned. OTTO VON GELDERN, *Secretary.*

Civil Engineers' Society of St. Paul.

NOVEMBER 4, 1895.—The regular meeting of the Civil Engineers' Society of St. Paul was called to order at the Society library at 8.30 P.M., by Vice-President Hilgard.

Present, eleven members and six visitors.

Minutes of previous meeting read and approved.

An adverse report of the Committee on International Literary and Artistic Association was accepted and committee discharged. All other committees were granted an extension of time.

Resolutions of thanks for courtesies extended to members of the Society were

passed in favor of the Western Society of Engineers, F. W. Cappelen, City Engineer of Minneapolis, and the Twin City Rapid Transit Co.

Messrs. Powell, Loweth and Woodman reported a resolution in favor of surveying the upper Mississippi, and the Secretary was instructed to telegraph the same to the Mississippi River Commission, at St. Louis, Mo.

Mr. Potts described the rebuilding of the Ketter River bridge approaches destroyed by the Hinkly fire. The remarkable record of framing and erecting an average of 100,000 feet of lumber per day was accomplished on this work.

Mr. Hilgard illustrated the method of hydraulic grading in vogue on the N. P. R. R. system. Under favorable circumstances the work of replacing worn-out wooden trestles with embankments is done at a cost of five cents per cubic yard.

Adjourned at 10.45.

C. L. Annan, *Secretary.*

Engineers' Club of St. Louis.

424th Meeting, November 6, 1895.—The club was called to order at 8.20 p.m., at 1600 Lucas Place, President Russell in the chair. Twenty-two members and five visitors present. The minutes of the 423d meeting were read and approved. The Executive Committee reported the doings of its 198th meeting, approving the application for membership of S. E. Freeman. He was balloted for and elected. Applications for membership were announced from Carl Barth, engineer Ranken & Fritsch Foundry and Machine Co.; Alfred W. French, Civil Engineer United States Government, Jefferson Barracks; and Richard Morey, City Engineer, Sedalia, Mo.

The Secretary announced the receipt of a detailed financial statement from the Secretary of the Association of Engineering Societies.

Prof. Chas. C. Brown's paper on "The Sewerage of Indianapolis" was then read by Mr. B. H. Colby. The paper explained the peculiar features of the problem, and was illustrated by drawings and maps showing the general features, as well as details of the several interesting forms of special construction. The methods of carrying on the work, and its extent and cost, were explained. The country being flat, little or no fall was available.

The discussion was participated in by Messrs. Robert Moore, Kineally, Flad, Olshausen, J. B. Johnson, Sherman, Pitzman, Hermann, Maltby, Bouton and President Russell.

Mr. Moore gave some further details of the situation, size of streams, etc. The life of iron work painted with asphalt was discussed. The difficulty of getting good construction in masonry was mentioned, as was also the subject of water pollution and protection of water sheds.

Adjourned. William H. Bryan, *Secretary.*

425th Meeting, November 20, 1895.—President Russell called the club to order at 8.25 p.m., twenty-six members and eight visitors being present.

The minutes of the 424th meeting were read and approved. The Executive Committee reported the doings of its 199th meeting. The names of John Dean, J. L. Duffy and J. A. Tiernan were dropped for delinquency. The applications for membership of C. G. L. Barth, Richard Morey and A. W. French, were approved. They were balloted for and elected.

On motion of Prof. J. H. Kinealy, the following parties were chosen a Committee on Nominations of Officers for 1896: E. D. Meier, P. N. Moore and William Bouton.

Resignations were announced from R. F. Grady and B. J. Arnold.

Prof. W. B. Potter, chairman of the club's Committee on Smoke Prevention, then addressed the club informally, explaining the steps which had brought about the present status of affairs in smoke abatement. The original agitation was begun in this club, and had resulted in the passage of two ordinances which had been in force for over two years, and were operating very satisfactorily. The movement had the backing of a popular organization known as the Citizens' Smoke Abatement Association, supported by nearly two thousand members. A Government official, who had recently investigated the subject, had reported that St. Louis had stopped 70 per cent. of its smoke, and was doing better than any other city in the country. The Professor explained the methods of measuring smoke and suggested that Government observers keep records of the smokiness of the atmosphere on different days. He also spoke of smoke from house chimneys, and the remedies possible. He then devoted special attention to the steam jet, as it is a very cheap remedy. He called attention to the fact that the personality of firemen entered more largely into this matter than any other single feature, and suggested that it would be well to license firemen, and thus raise the grade of intelligence and secure better results. A great many plants were defective in draft and had large air leakages. The attention which had been given the smoke problem had resulted in better boiler practice generally. The Professor thought that, on the whole, good progress had been made in the movement, and still better results could be expected in the future.

The discussion was participated in by Messrs. J. B. Johnson, P. N. Moore, Flad, Olshausen, Meier, Sherman, Bryan and Kinealy.

Adjourned. William H. Bryan, *Secretary.*

Civil Engineers' Club of Cleveland.

November 12, 1895.—Meeting of the Civil Engineers' Club of Cleveland, called to order by President Mordecai at about 7.45. Present, fifty-four members and visitors.

Minutes of the last meeting read and approved. Minutes of the Executive Committee meeting read and the resignation of Mr. W. W. Read reported.

Professor C. H. Benjamin reported in regard to the proposed excursion to Niagara Falls, and upon his motion a committee was appointed to attend to the matter.

The paper of the evening, by Mr. Frank C. Osborn, on Bridge Floors, was read, on account of his absence from the city, by his assistant, Mr. Bernard S. Green.

Mr. Osborn treated the subject historically, noting the progress in the design of the solid floors abroad and at home from the earliest times to the present. He states that the first bridge on record with solid wrought-iron floor is the Britannia, built in 1845. In America, the oldest solid iron trough floor for railroad bridge is that over the Willamette River, built in 1887.

Mr. Osborn gives the successive dates of introduction of about all the various forms that have now been in use, and brief description of the most important. He gives the requirements for a good railroad bridge floor as follows: Accessibility for

examination and painting, facilities for thorough and rapid draining, the use of shapes and sizes readily obtainable from the mills, simplicity of shop construction, cheapness of first cost and cost of maintenance, convenience of changing location of track laterally and direct, simple and effective connection to girders.

Discussion by Messrs. E. A. Handy, A. E. Brown and others.

Messrs. C. H. Benjamin, James Ritchie and E. S. W. Moore were appointed to arrange the Niagara Falls excursion.

The Club adjourned to the restaurant and partook of a light lunch.

FORREST A. COBURN, *Secretary.*

Boston Society of Civil Engineers.

NOVEMBER 20, 1895.—A regular meeting of the Society was held at its rooms, 36 Bromfield Street, Boston, at 7.50 P.M., President Albert F. Noyes in the chair. Sixty-nine members and visitors present.

The record of the last meeting was read and approved.

Messrs. Dwight L. Hubbard, Willis T. Knowlton, Elmer G. Manahan, Charles W. Sherman, George A. Soper, and Charles Temperley, were elected members of the Society.

The thanks of the Society were voted to Samuel Nott, an honorary member and Secretary of the Society from 1849 to 1874, for his gift of valuable books to the library.

The Treasurer spoke of the plan of raising a fund for fitting up the new rooms of the Society, by voluntary subscription, and stated that two liberal contributions had been received already. On motion it was voted that an appeal for subscriptions to the fund be issued in the notices of the next meeting.

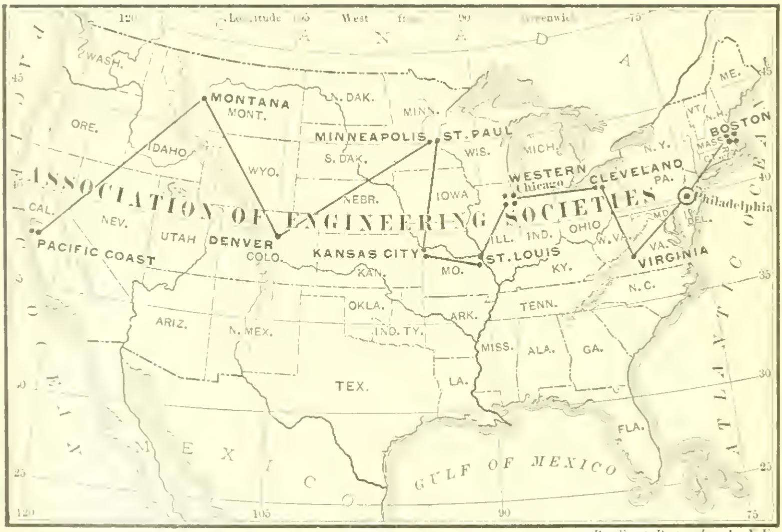
The resolution submitted at the last meeting by the Committee on Weights and Measures, in relation to a uniform standard of thicknesses for metals, was then considered, and after discussion, was amended so as to read:

Resolved, That the Boston Society of Civil Engineers earnestly deprecates the use of any of the wire and sheet metal, or other trade gauges now in vogue, and strongly urges the use of a decimal system for all such measurements.

Mr. R. W. Lesley, Treasurer of the American Cement Company, of Philadelphia, was then introduced, and read a paper entitled "Progress of the Manufacture of Portland Cement in America."

At the conclusion of the discussion of the paper, in which the members quite generally took part, a vote of thanks was passed to Mr. Lesley for the interesting paper which he had so kindly read.

Adjourned. S. E. TINKHAM, *Secretary.*



Bradley & Poates, Engr's N.Y.

Association of Engineering Societies.

Vol. XV. | December, 1895. | No. 6.

PROCEEDINGS.

Western Society of Engineers.

The 335th meeting of the Society was held in the Society's rooms, 1737 Monadnock Block, Chicago, on Wednesday evening, November 6, 1895. President Horton in the chair, and 40 members and guests present.

The minutes of the meeting of October 2d were read and approved.

The Secretary read the report of the Board of Directors—

At the meeting of the Board of Directors, held October 15, 1895, the following applications for membership were received and placed on file:

As Members—Messrs. Waldo H. Marshall and Charles Woodbury Melcher, both of Chicago.

At the meeting of the Board of Directors, held November 5, 1895, the following applications for membership were received and placed on file:

As Members—Messrs. Carl Haller, William T. Keating, LeRoy Kempton, Sherman and Leland L. Summers, all of Chicago.

The following named persons were elected to membership in the Society:

As Members—Waldo H. Marshall, Charles Woodbury Melcher and Lyman Smith, all of Chicago.

As Associate—Rudolph Link, Chicago.

The Treasurer reported a balance on hand October 1, 1895, of $1,561.79; and a balance on hand November 1, 1895, of $1,444.69.

Bills to the amount of $476.64 were approved and ordered paid.

Mr. Gerber, Chairman of the Excursion and Entertainment Committee, read an invitation from the Pioneer Rail Renewing Co., of Chicago, by Mr. James S. Prentice, Treasurer, inviting the Society to visit the works of that Company (formerly the North Chicago Rolling Mill Co.), on the 9th or 16th instant, preferably the 9th instant, and the invitation was accepted for that date.

Mr. Johnston, Chairman of the Committee, presented the following report:

"Your committee appointed to prepare a plan for the publications of the Society, and a revision of the Constitution and By-Laws, respectfully make report as follows:

"1. A draft of a resolution is submitted herewith, which, if adopted by the

Society, formulates a plan for publication. It is practically the rules under which the Philadelphia Society is proceeding, and which has been found satisfactory.

"2. A draft of a revised Constitution and By-Laws is submitted. The committee feels that the existing Constitution and By-Laws are very deficient, and recommends urgently the careful consideration of the document submitted, believing confidently that, though it may be in some respects imperfect, it certainly will be an exceedingly desirable substitute for what now exists."

(Signed) THOS. T. JOHNSTON,
CHAS. E. BILLIN.

Mr. Charles J. Roney, the third member of the Committee, briefly dissented, but from lack of time was unable to present a minority report.

It was voted that the report of the Committee be received for discussion.

The following resolution was presented, seconded and adopted :

"*Resolved*, That the report of the Committee on plans for publications and a revision of the Constitution and By-Laws be received, accepted and the Committee continued ; and, be it further

"*Resolved*, That the draft of the revised Constitution and By-Laws be printed and copies sent to all members of the Society at once, and that the matter be further considered at the adjourned meeting to be held on Friday, November 15, 1895, at 8 P.M."

The Secretary announced the death of Mr. Willard S. Pope, a Past President of the Society and one of its oldest members, who died, October 10th, at his home in Detroit, Mich.

On motion, it was voted that the President should appoint a Committee to prepare a memorial of our deceased member, Mr. Pope.

The President subsequently appointed as such Committee Messrs. George S. Morison, L. P. Morehouse and E. C. Carter.

The subject for discussion for the evening, "Methods of Power Testing for Motocycles," was introduced by Mr. Leland L. Summers, in a very interesting and instructive review of the general subject of motocycles, followed by a description by Mr. John Lundie of the machine and methods employed in testing motocycles to be used in the forthcoming motocycle contests in Chicago and vicinity. After an animated discussion of the subject, the meeting adjourned to meet in the Society's rooms on Friday, November 15, 1895, at 8 P.M.

CHARLES J. RONEY, *Secretary*.

ON Friday evening, November 15, 1895, the Society met pursuant to adjournment. President Horton in the chair and 25 members present.

It was moved and seconded that the resolution providing for publications be adopted. An amendment was offered that the third paragraph be stricken out. On vote the amendment was lost. The resolution was then by vote adopted.

On motion, the proposed revision of the Constitution, previously printed and mailed to members, was taken up for informal consideration, article by article, and in some cases section by section, and after such amendments as were approved, the articles were severally seconded by the meeting.

Articles I and II of the proposed revision of the By-Laws were in like manner considered, and, after amendment, were seconded by the meeting.

A resolution was then adopted that when the meeting adjourned it should adjourn to meet in the Society's rooms on Friday, November 22, 1895, at 8 P.M., for further consideration of the proposed revision of the Constitution and By-Laws.

Mr. George S. Morison here offered as an amendment to Article VI (by error printed as Art. IV), the following addition to Section 5 of said Article VI: "Any active member elected prior to December 31, 1895, and who shall have paid all fees, dues or assessments which may have accrued against him for a continuous period of twenty years (dues paid to the Civil Engineers' Club of the Northwest to be included in reckoning such twenty years), shall be excused from payment of annual dues thereafter," and asked that the same be considered at the next meeting.

On motion, the meeting then adjourned to meet in the Society's rooms on Friday, November 22, 1895, at 8 P.M. CHARLES J. RONEY, *Secretary.*

A SPECIAL meeting (336th of the Society) was held in Science Hall, Armour Institute of Technology, Chicago, on Thursday evening, November 21, 1895, at 8 o'clock. President Horton in the chair and 51 members and guests present.

A paper, "Application of Electric Power to Industrial Purposes," was presented by the author, Mr. George P. Nichols. The paper was illustrated by some thirty fine lantern views, and ofter discussion of the paper the meeting adjourned.

CHARLES J. RONEY, *Secretary.*

ON Friday evening, November 22, 1895, the Society met in the Society's rooms pursuant to adjournment from November 15th. Vice-President Johnston in the chair and 14 members present.

It was voted that a committee of ten members be appointed by the President to nominate candidates for the offices to be filled at the next annual election of the Society.

The meeting then proceeded to further consideration of the proposed revision of the Constitution and By-Laws, beginning at Article III of the By-Laws.

Articles III to VIII, inclusive, were considered, and after such amendments as were adopted, these articles were seconded by the meeting. The Amendment to Article VI, Section 5, proposed by Mr. George S. Morison at the meeting of November 15th, was voted upon and was rejected. Article IX was stricken out.

It was moved by Mr. Reynolds that the Constitution and By-Laws be seconded as a whole. Motion seconded and carried. The meeting then adjourned.

CHARLES J. RONEY, *Secretary.*

On November 9, 1895, by invitation of the Pioneer Rail Renewing Company, of Chicago, the works of that Company were visited and inspected by a considerable number of members. The Gates Iron Works were also visited, and the system of operation was fully inspected.

THE 337th meeting of the Society was held in the Society's rooms, 1737 Monadnock Block, Chicago, on Wednesday evening, December 4, 1895, at 8 P.M., with 41 members and guests present.

In the absence of the President and both Vice-Presidents, Mr. Alfred Noble was elected President *pro tempore.* The presentation and approval of the minutes of the November meetings of the Society, and the report of the Board of Directors were passed.

Mr. G. A. M. Liljencrantz, Chairman of the Committee, read a memoir of our deceased member, General O. M. Poe, and presented a series of resolutions regarding the death of General Poe, which resolutions were adopted by the Society. The memoir and resolutions will appear in the first number of the new journal of the Society.

A request for a better ballot on the proposed revision of the By-Laws of the Society, as amended at the November 6th meeting of the Society, was made by Messrs. Charles E. Billin, James J. Reynolds, Wm. T. Casgrain, G. A. M. Liljencrantz and P. H. Ashmead, and the Chairman announced that the requisite number of members having made such request, a letter ballot would be taken.

Mr. Clement F. Street, manager of the *Railway Review* engineer of the recent commission from the Field Columbian Museum, to visit Oriental railways, was then introduced and in a very entertaining manner presented notes of his observations of the engineering characteristics of the railways of Oriental countries, accompanied by the exhibition of a large number of photographs. A full report of Mr. Street's paper will appear in the new journal of the Society.

After a vote of thanks to Mr. Street, the meeting adjourned.

CHARLES J. RONEY, *Secretary.*

A SPECIAL meeting (338th of the Society) was held in the Society's rooms, on Thursday evening, December 19, 1895, at 8 P.M. President Horton in the chair and 26 members and guests present.

A paper, "Engineering Consequences of the Waterway Conventions at Cleveland, O., and Vicksburg, Miss., in 1895," was presented by Mr. Thos. T. Johnston, and the subject was very fully discussed by Messrs. F. P. Kellogg, L. E. Cooley, Isham Randolph, E. L. Cooley, Geo. A. Lederle, Chas. L. Harrison and Thos. T. Johnston.

It was voted that a committee be appointed to prepare a suitable expression to the President and faculty of the Armour Institute of Technology for the courtesies extended to the Society during the past year, and Mr. Isham Randolph was appcinted as such committee.

Adjourned. CHARLES J. RONEY, *Secretary.*

NOTE.—At the meeting of the Board of Directors, held December 3, 1895, the following applications for membership were received and filed: As Member—John C. Ostrup, Chicago. As Junior—Stillman Bingham Jameison, Chicago.

At the meeting of the Board of Directors, held December 19, 1895, the following applications for membership were received and filed: As Associates—James W. Gardner and Joseph S. Qualey, both of Chicago.

PUBLICATIONS.

The Publication Committee has reported to the Board of Directors that, for 1896, they will publish a journal containing about ninety pages of reading matter in each of six numbers. They have in sight a revenue from advertisements at this day sufficient to cover all probable expense of the publications for the year. They have entered into a contract for the work, and expect to have the first number out about the middle of January, 1896. The Committee reports that it is secure in regard to good matter for the journal, the contents of which will come under three general heads, as follows:

I. Papers and Discussions.
II. Topical Discussions.
III. Abstracts from Foreign Technical Papers.

CHARLES J. RONEY, *Secretary.*

Association of Engineers of Virginia.

The regular fall meeting of the Association of Engineers of Virginia was held in Roanoke on Saturday, November 23d, at 3 P.M. The meeting was called to order by the President, Mr. J. C. Rawn.

A paper by Prof. D. C. Humphreys, of Lexington, Va., on "Stream Measurements and Water Power in Virginia and West Virginia," was read by the Secretary (in the absence of Prof. Humphreys). The paper was particularly interesting to those of this section of the State. Referred, on motion, to the Publication Committee.

A paper was read by Prof. L. S. Randolph, of Blacksburg, Va., on "Cement Testing," special attention being given to the effects of heat. The results were interesting in showing that some cements increased and some decreased in strength from the effects of continued heat. Referred, on motion, to the Publication Committee.

Mr. J. C. Rawn gave a report of the Good Roads Convention, which met in Richmond in October, which report was very encouraging in that it showed a general interest all over the State in this very important matter.

Mr. M. E. Yeatman moved to amend Article IX of our Constitution and Rules, changing the first clause from "These rules may be amended at any annual meeting by a two-thirds vote of the members present, *not less than fifteen voting in the affirmative*," by leaving out the part in italics.

Mr. Wm. M. Dunlap moved that Article I of the Constitution be changed so as to read, "This Association shall be called 'The Association of Engineers of the Virginias.'"

Under the Constitution these two motions will have to lay over until the annual meeting in January, and then decided

Mr. S. A. White moved that a committee be appointed, with power to act, to investigate the matter of State laws in reference to the securing of claims for engineering services.

Motion carried, and Mr. S. A. White, Mr. Wm. M. Dunlap and Mr. H. A. Gillis were appointed on this committee.

JNO. A. PILCHER, *Secretary.*

Engineers' Club of St. Paul.

ST. PAUL, DECEMBER 2, 1895.—A regular meeting of the Civil Engineers' Society of St. Paul was called to order by President Stevens at 8.15 P.M. Present, eleven members and one visitor.

Minutes of previous meeting read and approved.

Mr. James D. Du Shane was elected a member.

The evening programme was necessarily waived, but several members volunteered interesting information.

Mr. Davenport described the three classes of earth slides which occur along the Red River of the North. The most remarkable have taken place two or three years after great floods (such as those of 1882 and 1893), when suddenly vast masses of the banks, several hundred feet wide and from thirty to fifty feet high, sink abruptly, and from 150,000 to 250,000 yards of the deeply underlying clay strata slide into the river, there being no horizontal movement of the upper mass.

Mr. Hilyard mentioned the fact that a pier of the N. P. R. R. bridge, at Bismarck, glided twenty-seven inches out of position, presumably on a bed of clay moistened by leakage from the city reservoir.

Mr. Crosby described his recent impressions of the sugar plantations and levees above New Orleans.

Mr. Estabrook stated that a saving of about 20 per cent. has been effected by substituting a triple for a double expansion engine at the Washburn-Crosby flour mills in Minneapolis. C. L. ANNAN, *Secretary.*

Engineers' Club of St. Louis.

426TH MEETING, DECEMBER 4, 1895.—The annual meeting was held at 1600 Lucas Place, with twenty-three members and three visitors present.

President Russell called the Club to order at 8.30 P.M. The Executive Committee reported the doings of its 200th meeting. Applications for membership were announced from Walter S. Brown, S. F. Crecelius and Ora E. Overpeck.

The President read the annual report of the Executive Committee. It was approved and ordered filed. On motion it was ordered that the Executive Committee be authorized to arrange with the Missouri Historical Society for an extension of the present contract for a term not greater than three years, on the same or better terms than heretofore.

The annual reports of the Secretary and Librarian were then read, and, on motion, accepted and ordered filed.

The Treasurer read his annual report, which was, on motion, referred to the Executive Committee to be audited.

The Standing Committee on Eads Monument asked to be continued. So ordered.

The Committee on Boulevards submitted a report which was ordered received and the committee discharged.

The Committee on Library submitted a report. It was accepted and the committee continued.

At the suggestion of Mr. Bryan, the Committee on Boiler Legislation was discharged, and that on Standard Gauges for Thickness continued.

The Committee on Nominations of Officers for 1896 reported as follows:

For President—J. A. Ockerson.

For Vice-President—Edward Flad.

For Secretary—William H. Bryan.

For Treasurer—Thomas B. McMath.

For Librarian—W. A. Layman.

For Directors—S. B. Russell and Carl Gayler.

For Representatives on the Board of Managers of the Association of Engineering Societies—J. B. Johnson and W. E. Barns.

Additional nominations being called for, B. H. Colby and N. W. Eayrs were placed in nomination for Vice-President, and William Bouton, Julius Baier, M. L. Holman and B. L. Crosby for directors.

The Secretary acknowledged the receipt of a copy of the souvenir prepared by the local chapter of the American Institute of Architects at its recent convention in this city.

Ordered that the Executive Committee arrange for a supper on the evening of December 18th.

C. H. Sharman then read a paper prepared by R. J. McCarthy, of Kansas City, on the subject of smoke prevention, which paper had already been read by the author before the Engineers' Club of Kansas City. It was an able and exhaustive presentation of the subject, and was discussed at some length by Messrs. Bryan, Kinealy, Russell, and Wheeler. Ordered that the thanks of the Club be extended to both the author and reader of the paper.

Prof. J. H. Kinealy then exhibited a new form of draught gauge, which remedied many of the troubles incident to the ordinary forms of apparatus.

WILLIAM H. BRYAN, *Secretary.*

427TH MEETING, DECEMBER 18, 1895.—The annual dinner was given at the Mercantile Club, the hour of the meeting being 7.30 P. M. At 8.15, those present sat down to dinner, President Russell occupying the chair, with forty-five members and six visitors present.

After justice had been done to the dinner, President Russell called the club to order, after which the Secretary read letters of regret from: Horace E. Horton, President, Western Society of Engineers; A. F. Noyes, President, Boston Society of Civil Engineers; and Augustus Mordecai, President, Civil Engineers' Club of Cleveland. He then read the report of the 203d meeting of the Executive Committee, giving the result of the letter ballot for officers for 1896 as follows:

For President—J. A. Ockerson.

For Vice-President—Edward Flad.

For Secretary—William H. Bryan.

For Treasurer—Thomas B. McMath.

For Director—M. L. Holman.

For Librarian—W. A. Layman.

For Members Board of Managers of the Association of Engineering Societies—J. B. Johnson and W. E. Barns.

There having been no election for the second director, the committee ruled that the oldest director, Mr. Crosby, retire, and Mr. Bouton continue to serve until his successor was elected. On motion it was ordered that the matter of election of an additional director be deferred until the next meeting.

Retiring President Russell then resigned the chair in favor of the incoming president, Mr. J. A. Ockerson, who was seated at the opposite end of the table. After brief remarks, President Ockerson called on Mr. Russell for an address, which the latter then delivered, his subject being, "The Work of Engineers' Clubs." Other addresses were afterwards made as follows: "Engineers' Clubs, Their Best Fields of Usefulness," Robert Moore; "The Engineer at Home and Abroad," Julius Pitzman; "The Engineer of the Future," Richard McCulloch; "The Association of Engineering Societies," J. B. Johnson; "The Engineers' Club of St. Louis," C. M. Woodward.

Mr. George H. Reynolds, of Chicago, being called upon, made some brief remarks on "The Standing and Character of the Engineer." Adjourned.

WILLIAM H. BRYAN, *Secretary.*

Technical Society of the Pacific Coast.

REGULAR MEETING, DECEMBER 6, 1895.—Called to order at 8.30 P.M. by President Dickie.

The minutes of the last regular meeting were read and approved.

Dr. Willis E. Everette, of Tacoma, Washington, was elected to membership by regular ballot.

The name of John Cotter Pelton, Architect, of San Francisco, was proposed for membership by H. T. Bestor, G. W. Percy and Otto von Geldern. Referred to the Executive Committee for action.

In compliance with Section 2, Article II, of the By-Laws, the following members were duly elected a Nominating Committee to present a ticket at the next regular meeting for the election of the Society's officers for the ensuing year:

John Richards,
C. E. Grunsky,
H. C. Behr,
A. d'Erlach,
Ross E. Browne.

Mr. Otto von Geldern explained to the members present the cyclotomic method of transit observations, introducing a novel instrument for the engineer's use in the field.

Mr. John Cotter Pelton then read the paper of the evening, entitled "Released Ashlar," submitting for discussion the problem of attaching slabs of marble to the exterior of the walls in building construction, in which the façade is simply ornamented to the extent of a marble or other finish.

This paper led to an interesting discussion, which occupied the evening of the meeting.

It was ordered, upon motion, that the paper be edited by the Technical Society and submitted for publication in the JOURNAL OF THE ASSOCIATION OF ENGINEERING SOCIETIES. Adjourned.

OTTO VON GELDERN, *Secretary*.

The Civil Engineers' Club of Cleveland.

MEETING of the Civil Engineers' Club of Cleveland in the Assembly Room of the School Council, December 10, 1895, called to order at 8 P.M. by President Mordecai. Present, eighty-seven members and visitors. On motion, the reading of the minutes was dispensed with.

Application of J. S. Covert for admission as Active Member was read. Report of the election of S. E. Tinkham as Chairman, and J. C. Trautwine, Jr., as Secretary of the Association of Engineering Societies, was read.

The speaker of the evening, Mr. Geo. De Leval, was introduced by the President, and read his interesting paper on "Crank and Fly Wheel versus Direct Compensating Pumping Engines," illustrated by reference to blue prints of different types and parts of engines.

Discussion was engaged in by Mr. H. G. H. Tarr, Mr. J. F. Holloway, and others.

Resolutions were adopted thanking the School Council for the use of their room for the evening, and thanking Mr. De Leval for his interesting lecture.

At 10 P.M. adjourned. F. A. COBURN, *Secretary*.

Montana Society of Civil Engineers.

Helena, Mont.—The regular monthly meeting of the Montana Society of Civil Engineers was held Saturday evening, December 14th, at the society's headquarters in the Helena Board of Trade Rooms. The applications for membership of John Randolph Parks and John Cameron Patterson were read, and the Secretary was directed to send out letter ballots to the members, to be canvassed at the next regular meeting.

Charles G. Griffith was elected trustee, to fill the vacancy caused by the resignation of Walter S. Kelley.

A letter from Prof. J. B. Johnson, Chairman of the Board of Managers of the Association of Engineering Societies, was read. It stated that at the last election of the Board, S. E. Tinkham, of Boston, had been chosen Chairman, and John C. Trautwine, Jr., of Philadelphia, Secretary. President Keerl was selected to draw a set of resolutions expressing the appreciation of the society for Prof. Johnson's untiring work for the good of the Association during his term as Chairman.

Several members had sent written discussions of John H. Farmer's paper on Water Power by Electrical Transmission in Relation to the Mills and Manufactures of Helena, and it was expected these would be read at this meeting, but, owing to the importance of the subject, and to secure a fuller discussion, it was voted to have the paper and the discussions now on hand printed in full and sent to each member of the society and to others interested in the subject, with the request that they each send a written discussion to the Secretary in time for the annual meeting to be held in this city January 11, 1896, at which time a number of engineers from various parts of the State will be present. It is expected that a number of engineers will give this matter serious consideration, and their ideas reduced to writing will form a most interesting topic for discussion at the annual meeting.

The meeting adjourned to January 11, 1896.

F. J. Smith, *Secretary.*

Boston Society of Civil Engineers.

December 18, 1895.—A regular meeting was held at the Society rooms, 36 Broomfield Street, Boston, at 7.45 p.m. Past President, Frederic P. Stearns in the chair. Eighty-three members and visitors present.

The record of the last meeting was read and approved.

Messrs. Joseph S. Craigue, Arthur W. Dean, Arthur C. Grover, Joseph P. Lyon, Irving E. Moultrop, Franklin H. Robbins, George G. Shedd, Gordon H. Taylor and De Witt C. Webb were elected members, and Mr. Heber B. Clewley an associate of the Society.

Mr. Fred. Brooks, for the Committee appointed to prepare a memoir of Willis H. Hall, submitted its report, which was read and accepted.

The Chairman announced the death of Horace L. Eaton, a member of the Society, which occurred on November 23, 1895, and on motion the President was requested to appoint a committee to prepare a memoir.

The thanks of the Society were voted to the Walworth Manufacturing Co., of Boston, for courtesies shown its members on the occasion of the visit to the Company's works at South Boston this afternoon.

The following resolution, which was considered at the last meeting, came before the Society for adoption:

Resolved, That the Boston Society of Civil Engineers earnestly deprecate the use of any of the wire and sheet metal, or other trade gauges now in vogue, and strongly urge the use of a decimal system for all such measurements.

Mr. A. H. Howland spoke very strongly in opposition to the resolution. Upon a vote being taken, eighteen were in favor of its adoption and two against.

Mr. George S. Rice then delivered an informal address entitled "Some Notes Concerning the New Croton Aqueduct." Mr. Rice gave a general description of the work, illustrating the important features by over 100 lantern views, and spoke in more detail of the method of grouting which was used where defective work was discovered in the aqueduct.

Adjourned. S. A. TINKHAM, *Secretary*.

Willis H. Hall.—A Memoir.

BY FREDERICK BROOKS, A. M. MATTICE AND F. W. DEAN, COMMITTEE OF THE BOSTON SOCIETY OF CIVIL ENGINEERS.

[Read December 18, 1895.]

WILLIS H. HALL, son of Edward B. and Ellen N. Hall, was born December 23, 1860, at West Westminster, Vermont. His ancestors had long lived in New England and had been engaged in farming. His education, after leaving the common school, was obtained at the Vermont Academy, at Saxton's River, Vermont, near his home, and at the Polytechnic Institute, at Worcester, Mass., where he studied for about a year. He was employed for a time at Hopedale, Mass., but his principal occupation was in the office of E. D. Leavitt, at Cambridgeport, where he was employed as draughtsman from September 5, 1882, to September 1, 1888, and again from December 28, 1891, to June 2, 1894. He also did some professional work in San Francisco, having gone to California to get the benefit of a mild climate. The latter part of his life was a continued struggle with that prevalent disease of New England, pulmonary consumption, of which he died at Fresno, California, August 26, 1895.

In his professional work he was conscientious, thorough and intelligent, always wanting to know the reason why. He was obliging and agreeable in all his intercourse, and his sterling character might be a worthy example for us all, though his life was without exciting incidents and was brought prematurely to a close.

In November, 1887, he married Miss Elmira F. Cobb, of Cambridge, Mass., who survives him.

Engineers' Club of Minneapolis.

MINNEAPOLIS, Minn., December 23, 1895.—A meeting of the Engineers' Club of Minneapolis was held at the office of the City Engineer, City Hall, at 8 P.M., the President in the chair.

Minutes of previous meetings were read and approved, after correcting those of last meeting relating to statement of indebtedness, making them read "which sum was entirely a balance due to the JOURNAL."

A statement was again made of the account due for the JOURNAL, of the money on hand, and the amounts due the Club from its members, after informal discussion.

W. R. Hoag moved that the Secretary and Treasurer be instructed to send to J. C. Trautwine, Jr., Secretary of the Association of Engineering Societies, Seventy-five Dollars ($75) and to notify him that the balance of the amount already due would be send him by February 1, 1896.

That from January 1, 1896 (for the JOURNAL of 1896), a new mailing list will be furnished, and that Mr. Trautwine be instructed to send no JOURNALS on account of this Club, to any one not upon the new list.

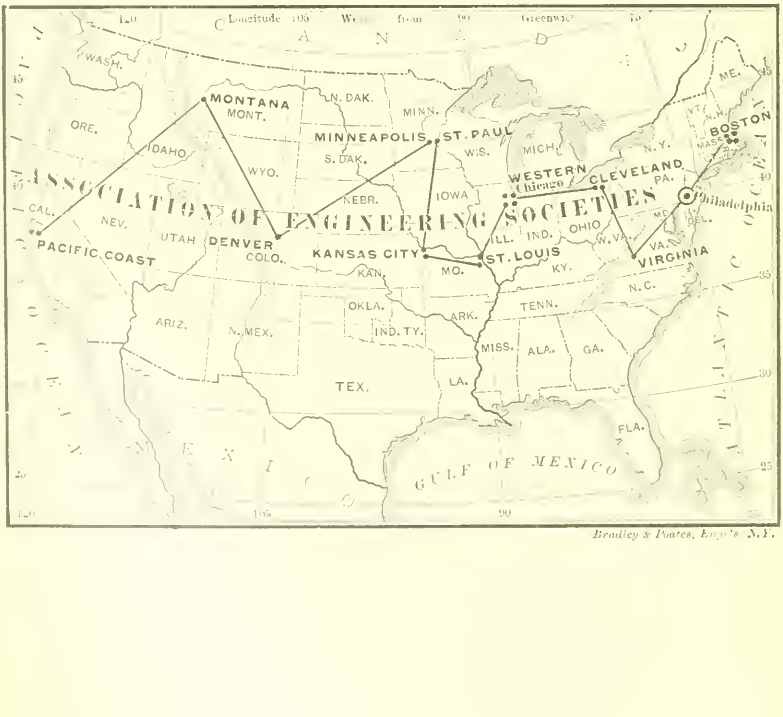
That the Secretary place no name on the new list until the money is paid him for the JOURNAL of 1896. Carried unanimously.

It was then moved that the Secretary be instructed to see all the members of the Club before January 1, 1896, and ask them to take the JOURNAL and pay him the Three Dollars ($3) in advance, or send in their resignations, or the Club will take suitable action at its next meeting. Carried.

G. D. Shepardson moved that an assessment of Three Dollars ($3) be levied on each member of the Club to apply on the JOURNAL for 1896. Carried.

On motion adjourned to meet in January, as the annual meeting to elect officers.

ELBERT NEXEN, *Secretary.*



Bradley & Poates, Engr's N.Y.

INDEX TO CURRENT LITERATURE.

NOTICE.

Notice is hereby given to the readers of this Journal that after the completion of the current volume, with the December number, 1895, this Index Department will be discontinued. This action has been taken by the Board of Managers of the JOURNAL in view of the elaborate and more complete index to current engineering and other technical literature, which is now published in the *Engineering Magazine*. The JOURNAL OF THE ASSOCIATION OF ENGINEERING SOCIETIES has maintained this Index Department for the past eleven years at an annual expense for composition, printing and republication in the annual summary, of about $1,000. This Index has been entirely unique in its characteristics, but within the last few months the Index published by the *Engineering Magazine* has been prepared directly on the lines which have been followed in the preparation of our own Index Department. Since the editor of that journal proposes to maintain his Index on these lines, and to publish an annual summary as a separate volume, which will be sold separately from the *Magazine*, the Board of Managers of this journal has decided to abandon the work, and to recommend the readers of this journal who value the Index Department to subscribe for the *Engineering Magazine*, and so encourage the editor of that journal to maintain this department in an adequate manner.

The editor of that magazine has also agreed to republish the index notes which have appeared in this journal for the last four years in a bound volume, similar to that published some years ago, containing the index notes for the seven preceding years.

In thus taking leave of the many friends who have encouraged the manager of this department in the past, by their appreciative recognition of the service rendered them in its preparation, he bespeaks for the editor of the *Engineering Magazine* the same kind consideration and helpful assistance.

J. B. JOHNSON,
Manager Index Department, Chairman Board of Managers.

THE repetition of titles in this issue of the annual index in place of the use of dashes, as heretofore, is due to the use of the linotype machine in setting the type. By its use the total cost of the index has been reduced about one-third.

LIST OF PERIODICALS INDEXED.

Following the title of each periodical is given, in italics, the abbreviation by which it is referred to in the Index.

For alphabetical list of abbreviated titles, see page iv.

UNITED STATES.

ANNUAL.

American Institute of Mining Engineers, Transactions of the — (*Trans. A. I. M. E.*), 13 Burling Slip, New York; per year, $5.

American Society of Mechanical Engineers, Transactions of the — (*Trans. A. S. M. E.*), 12 West Thirty-first Street, New York.

American Water Works Association, Proceedings of Annual Meetings of the — (*Am. W. W. Ass'n.*), 95 William Street, New York; per year, $1.

Society of Naval Architects and Marine Engineers, Transactions of the—(*Trans. N. A. & M. E.*), W. L. Capps, Secretary, 1710 F Street N. W., Washington, D. C.; $10 per annual volume.

QUARTERLY.

Engineers' Club of Philadelphia, Proceedings of the — (*Proc. Eng. Club Phila.*), 1122 Girard Street, Philadelphia, Pa.; per year, $2.

New England Water Work Association, Journal of the — (*Jour. N. E. W. W. Assn.*), New London, Conn.; per year, $2; single copies, 75 cents.

School of Mines Quarterly (*Sch. Mines Quart.*), Columbia College, New York City; per year, $2; single copy, 50 cents.

Technology Quarterly and Proceedings of the Society of Arts (*Tech. Quart.*), Massachusetts Institute of Technology, Boston, Mass.; per year, $3.

United States Naval Institute, Proceedings of the — (*Proc. U. S. N. I.*), United States Naval Institute, Annapolis, Md.; per year, $3.50; single copy, $1.

MONTHLY.

SOCIETIES.

American Institute of Electrical Engineers, Transactions o the — (*Trans. A I. E. E.*), 12 West Thirty-first Street, New York City.

American Society of Civil Engineers, Transactions of the — (*Trans. A. S. C. E.*), 127 East Twenty-third Street, New York; per year, $10.

Association of Engineering Societies, Journal of the — (*Jour. Assn. Eng. Socs.*), Philadelphia: per year $3; single copy, 30 cents.

Engineers' Society of Western Pennsylvania, Proceedings of—(*Proc. Eng. Soc. W. Pa.*), Allegheny, Pa; per year, $7; single copy, 75 cents.

Franklin Institute, Journal of the — (*Jour. Frank. Inst.*), Franklin Institute, Philadelphia, Pa.; per year, $5; single copy, 50 cents.

PERIODICALS.

American Engineer and Railroad Journal (*Am. Eng. & R. R. Jour.*), 47 Cedar Street, New York; per year, $3; single copy, 25 cents.

Cassier's Magazine (*Cassier*), World Building, New York; per year, $3; single copy, 25 cents.

Clay Worker (*Clay W.*), Indianapolis, Ind.; per year, $2.00.

Engineering Magazine (*Eng. Mag.*), 47 Times Building, New York; per year, $3; single copy, 25 cents.

Engineering Mechanics (*Eng. Mech.*), 430 Walnut Street, Philadelphia, Pa.; per year, $1; single copy, 10 cents.

Irrigation Age (*Irrigation Age*), Chicago, Ill.; per year, $2.

Master Steam Fitter (*Mst. Stm. Fitter*), 218 La Salle Street, Chicago, Ill.; per year, $1; single copy, 10 cents.

Municipality and County. The — (*Munic & Co.*) Niagara Publishing Co., 202 Main St., Buffalo, N. Y.; per year, $2.

Paving and Municipal Engineering (*Pav. & Munic. Eng.*), Municipal Engineering Co., 44 Chamber of Commerce, Indianapolis, Ind.; per year, $2; single copy, 25 cents.

Power (*Power*), World Building, New York; per year, $1; single copy, 10 cents.

Railway Engineering and Mechanics (*Ry. E. & M.*), 816 The Rookery, Chicago, Ill.; per year, $1; single copy, 10 cents.

Safety Valve (*Sy. Valve*), 55 Liberty Street, New York; per year, $1; single copy, 10 cents.

Street Railway Journal (*St. Ry. Jour.*), World Building, New York; per year, $4; single copy, 35 cents.

Stone (*Stone*), Chicago; per year, $2; single copy, 25 cents.

Street Railway Review (*St. Ry. Rev.*), 269 Dearborn Street, Chicago, Ill.; per year, $2; single copy, 25 cents.

WEEKLY.

American Architect (*Am. Arch.*), Ticknor & Co.; 211 Tremont Street, Boston, Mass.; single copy, 15 cents.

American Machinist (*Am. Mach.*), 96 Fulton Street, New York; per year, $2; single copy, 10 cents.

Boston Journal of Commerce (*Bos. Jour. Com.*), 128 Purchase Street, Boston, Mass.; per year, $3; single copy, 6 cents.

Electrical Engineer (*Elec. Engr.*), 203 Broadway, New York; per year, $3.

Electrical World (*Elec. World*), 177 Times Building, New York; per year, $3; single copy, 10 cents.

Engineering and Mining Journal (*E. & M. Journal*), 253 Broadway, New York; per year, $5; single copy, 15 cents.

Engineering News (*Eng. News*), Tribune Building, New York; per year, $5; single copy, 15 cents.

Engineering Record (*Eng. Rec.*), 277 Pearl Street, New York; per year, $5; single copy, 12 cents.

Railroad Gazette (*R. R. Gaz.*), 32 Park Place, New York; per year, $4.20; single copy, 10 cents.

Scientific American Supplement (*Sci. Am. Sup.*), 361 Broadway, New York; per year, $5; single copy, 10 cents.

Electric Railway Gazette (*Elec. Ry. Gaz.*), Monadnock Block, Chicago; per year, $3; single copy, 25 cents.

CANADA.

Canadian Society of Civil Engineers, Transactions of the — (*Trans. Can. Soc. C. E.*), McGill University, Montreal.

GREAT BRITAIN.

Electrical Review (*Elec. Rev.*), 22 Paternoster Row, London, E. C.; weekly; per year, 21s, 8d; single copy, 4d.

Engineer, The — (*Lon. Engineer*), London, England; weekly; per year, $10; single copy, 25 cents.

Engineering (*Lon. Eng.*), London, England; weekly; per year, $10; single copy, 25 cents.

Engineering Review (*Eng. Rev.*), 29 Great George Street, S. W., England; monthly; single copy, 6d.

Institution of Civil Engineers, Proceedings of the — (*Proc. Inst. C. E.*), 25 Great George Street, Westminster, S. W., London, England.

Institution of Mechanical Engineers, Proceedings of the — (*Proc. Inst. Mech. Engs.*), 19 Victoria Street, Westminster, S. W., London, England.

Mechanical World (*Mech. World*), Manchester, England; weekly; per year, 8s, 8d.

Practical Engineer (*Prac. Engr.*), 2 Amen Corner, London, E. C., England; weekly; per year, 10s.

Railway Engineer (*Ry. Eng.*), 8 Catherine Street, Strand, W. C., London, England; monthly; single copy, 1s.

INDIA.

Indian Engineer (*Ind. Engr.*), Calcutta, India; per year, 20 Rs.

Indian Engineering (*Ind. Engng.*), Calcutta, India, weekly; per year, 18s; single copy, 8 annas.

FRANCE.

Ponts et Chaussées, Annales des — (*Annales des P. & C.*), monthly, Vve. Ch. Dunod, 49 Quai des Augustins, Paris, France.

Société des Ingénieurs Civils, Mémoires de la — (*Mems. Soc. Ing. Civils*), monthly, 10 Cité Rougement, Paris.

GERMANY, AUSTRIA AND SWITZERLAND.

Archiv für Eisenbahnwesen (*Arch. f. Eisenbw.*), bi-monthly, Julius Springer, Berlin, Germany; per year, 12 marks.

Civilingenieur, Der — (*Civ. Ing.*), monthly.

Deutsche Bauzeitung (*Deutsche Bztg.*), semi-weekly, Berlin, Germany; per year, 12 marks.

Journal für Gasbeleuchtung und Wasserversorgung (*Jour. f. Gasb. u. Wasserv.*), three times a month, 11 Glückstrasse, Munich, Germany; per year, 20 marks.

Praktische Maschinen-Constructeur, Der— (*Pr. Msch. Cnstr.*), bi-weekly, Leipzig-Gohlis, Germany; per year, 16 marks.

Schweizerische Bauzeitung (*Schw. Bztg.*), German and French, 32 Brandschenkestrasse, Zurich.

Zeitschrift des Oesterreichischen Ingenieur und Architekten Vereins (*Ztsch. Oest.*), weekly.

Zeitschrift des Vereines Deutscher Ingenieure (*Ztsch. Ver. Ing.*), weekly, Berlin, Germany; per year, 32 marks.

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Alphabetical List of Abbreviated Titles

OF PERIODICALS INDEXED.

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Am Arch. *American Architect*, Boston ; weekly.
Am Eng & R R Jour. *American Engineer & Railroad Journal*, New York ; monthly.
Am Mach. *American Machinist*, New York ; weekly.
Am. W. W. Assn. *Proceedings, American Water Works Association*, New York ; annual.
Annales des P & C. *Annales des Ponts et Chaussées*, Paris, France ; monthly.
Arch f Eisenbw. *Archiv für Eisenbahnwesen*, Berlin, Germany ; bi-monthly.
Bos. Jour. Com. *Boston Journal of Commerce*, Boston, Mass.; weekly.
Cassier. *Cassier's Magazine*, New York ; monthly.
Civ Ing. *Der Civilingenieur ;* monthly.
Clay W. *Clay Worker*, Indianapolis, Ind.; monthly.
Deutsche Bztg. *Deutsche Bauzeitung*, Berlin, Germany ; semi-weekly.
E & M Journal. *Engineering and Mining Journal*, New York ; weekly.
Elec Eng. *The Electrical Engineer*, New York ; weekly.
Elec Rev. *Electrical Review*, London, Eng.; weekly.
Elec World. *The Electrical World*, New York ; weekly.
Eng Mag. *The Engineering Magazine*, New York ; monthly.
Eng Mech. *Engineering Mechanics*, Philadelphia, Pa.; monthly.
Eng News. *Engineering News*, New York ; weekly.
Eng Rec. *Engineering Record*, New York ; weekly.
Eng Rev. *Engineering Review*, London, Eng.; monthly.
Ind Engng. *Indian Engineering*, Calcutta, India ; weekly.
Ind. Engr. *Indian Engineer*, Calcutta, India ; weekly.
Irrigation Age. *The Irrigation Age*, Chicago, Ill.; monthly.
Jour Assn Eng Socs. *Journal of the Association of Engineering Societies*, Philadelphia ; monthly.
Jour f Gasb u Wasserv. *Journal für Gasbeleuchtung und Wasserversorgung*, Munich, Germany ; three times a month.
Jour Frank Inst. *Journal of the Franklin Institute*, Philadelphia, Pa. ; monthly.
Jour N E W W Assn. *Journal of the New England Water Work Association*, New London, Conn. quarterly.
Lon Eng. *Engineering*, London, England ; weekly.
Lon Engineer. *The Engineer*, London, England ; weekly.
Mst. Stm. Fitter. *Master Steam Fitter*, Chicago, Ill.; monthly.
Mech World. *The Mechanical World*, Manchester, England ; weekly.
Mems Soc Ing Civ. *Mémoires de la Société des Ingénieurs Civils*, Paris ; monthly.
Munic & Co. *Municipality and County, The——*, Buffalo, N. Y.: monthly.
Pav & Munic Eng. *Paving and Municipal Engineering*, Indianapolis, Ind. ; monthly.
Power. *Power*, New York ; monthly.
Pr Msch Cnstr. *Der Praktische Maschinen-Constructeur*, Leipsic.
Prac. Engr. *Practical Engineer*, London ; weekly.
Proc Eng Club Phila. *Proceedings of the Engineers' Club of Philadelphia*, Philadelphia, Pa.; quarterly.
Proc Eng Soc W Pa. *Proceedings of Engineers' Society of Western Pennsylvania*, Pittsburg, Pa. ; monthly.
Proc Inst C E. *Proceedings of the Institution of Civil Engineers*, London, England
Proc Inst Mech Engrs. *Proceedings of the Institution of Mechanical Engineers*, London, England.
Proc U S N I. *Proceedings of the United States Naval Institute*, Annapolis, Md. ; quarterly.
R R Gaz. *Railroad Gazette*, New York ; weekly.
Ry E & M. *Railway Engineering and Mechanics*, Chicago, Ill. ; monthly.
Ry Eng. *The Railway Engineer*, London, England ; monthly.
Sch Mines Quart. *School of Mines Quarterly*, New York City.
Schw Bztg. *Schweizerische Bauzeitung*, Zurich ; German and French ; weekly.
Sci Am Sup. *Scientific American Supplement*, New York ; weekly,
Stone. *Stone*, Chicago, Ill. ; monthly.
Elec Ry Gaz. *The Electric Railway Gazette*, Chicago, Ill. ; weekly
St Ry Jour. *Street Railway Journal*, New York ; monthly.
St Ry Rev. *Street Railway Review*, Chicago, Ill.; monthly.
Sy Valve. *Safety Valve*, New York ; monthly.
Tech Quart. *Technology Quarterly and Proceedings of the Society of Arts*, Boston, Mass
Trans A I E E. *Transactions of the American Institute of Electrical Engineers*, New York City.
Trans A I M E. *Transactions of the American Institute of Mining Engineers*, New York.
Trans A S C E. *Transactions of the American Society of Civil Engineers*, New York ; monthly.
Trans A S M E. *Transactions of the American Society of Mechanical Engineers*, New York
Trans Can Soc C E. *Transactions of the Canadian Society of Civil Engineers*, Montreal.
Trans N A & M E. *Transactions of the Society of Naval Architects and Marine Engineers*, Washington, D. C. ; annual.
Ztsch Oest. *Zeitschrift des Oesterreichischen Ingenieur und Architekten Vereins ;* weekly.
Ztsch Ver Ing. *Zeitschrift des Vereins Deutscher Ingenieure*, Berlin, Germany ; weekly.

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Abstract of paper on the design of Air Pumps, by F. H. Bailey, U. S. N., from the Journal of the Am. Soc. of M. E. —Prac. Engr., Feb. 8, 1895.

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An interesting paper by A. W. Koster, giving rules for the design of such valves and also several examples.—Ztsch Ver. Ing., Sept. 7, 1895.

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How to delineate alternating current curves when the alternator is inaccessible. By J. A. Flemming.—Elec. Engr., March, 1895.

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AMBULANCE, Stret Railway ——.
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Their contemporary achievements and teachings. Fully illustrated. —Eng. Mag., Vol. X, No. 2, pp. 203-226 (1895).

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Method of regulating the mechanical draft of boilers automatically, by which the steam pressure is kept constant. Illustrated.—Power, May, 1895, p. 8.

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Drawbridge of 23 ft. span of economical and efficient construction. General plans. Illustrated. C. E. Burroughs. —Eng. Rec., Aug. 10, 1895, p. 184.

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